ANNUAL REVIEW

# JOURNAL OF Metals

TECHNOLOGY · PRACTICE

MARCH 1949

**Planned Economy**

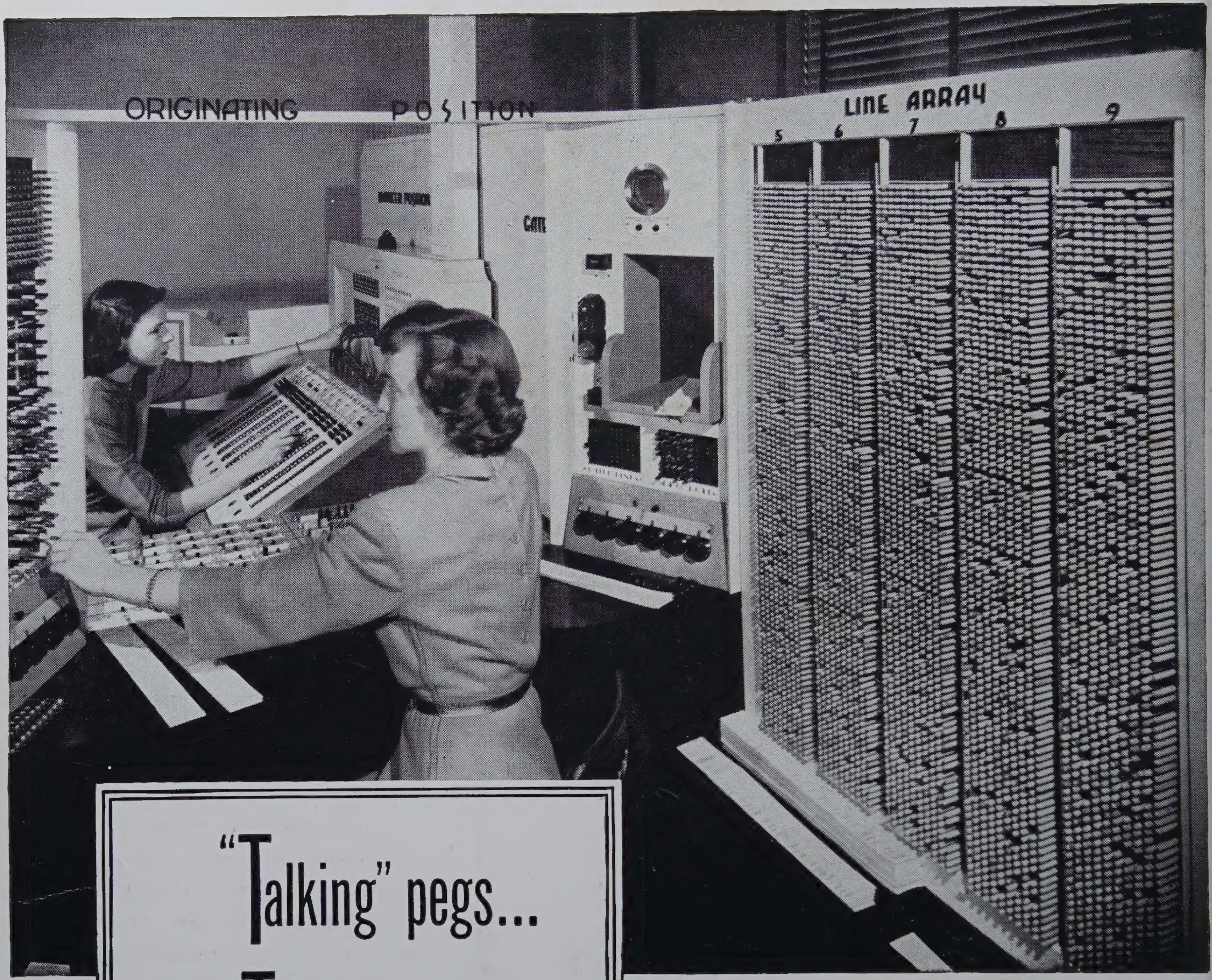
•

**Secondary Metals**

•

**ANNUAL REVIEW:**
**Physical Metallurgy**
**Production of:**
**Iron and Steel**
**Ferroalloy Metals**
**Cu, Zn, Pb, Al, Mg**

A MONTHLY PUBLICATION OF THE
AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS
*METALS BRANCH*



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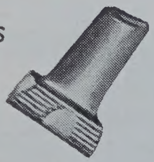

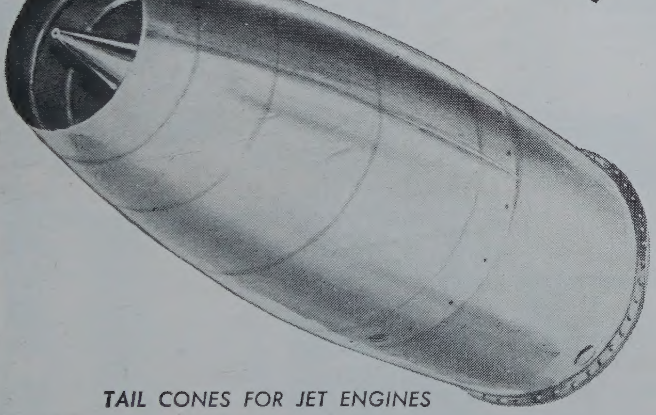

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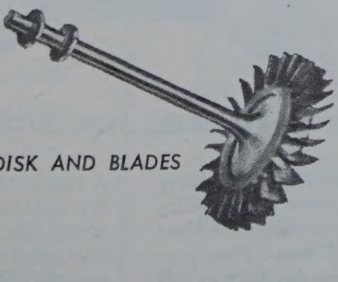

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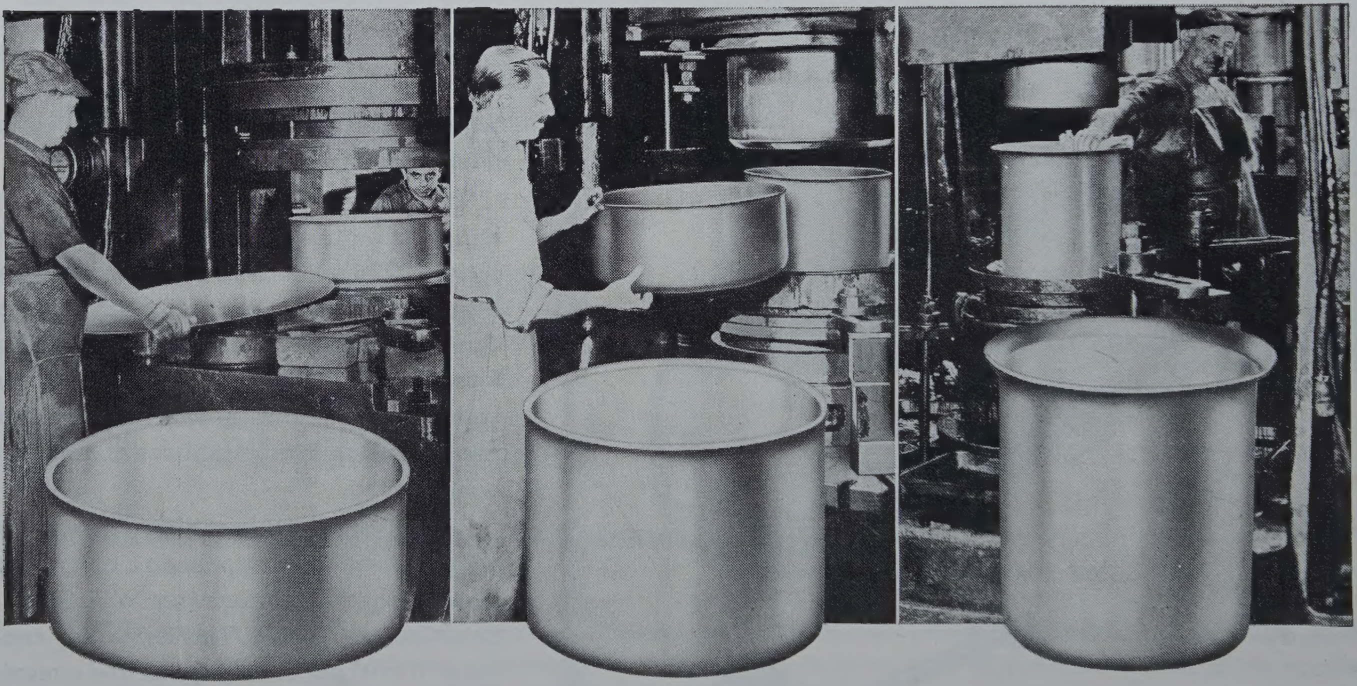

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MARCH 1949
Volume 1, No. 3

COVER PHOTOGRAPH represents scrapped aluminum airplane cylinders, to be refined into secondary aluminum ingots—see first feature article.

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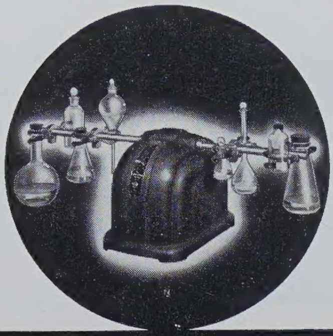
**AIME also publishes *Mining Engineering* and *Journal of Petroleum Technology.***

**The deadline for Fall Meeting papers of IMD will be May 1, 1949.**



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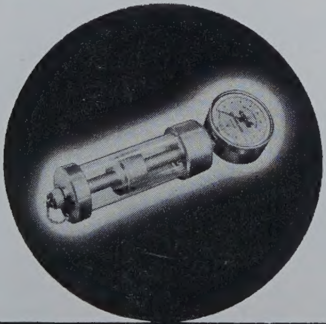

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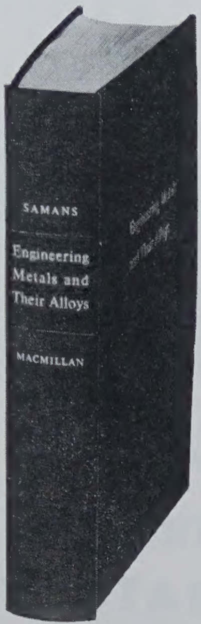
### New England AIME Meets

Under the chairmanship of Vincent T. Malcolm of the Chapman Valve Mfg. Co., Indian Orchard, Mass., plans are progressing rapidly for the third annual New England Regional Conference of the Institute of Metals Division, AIME. The meeting will be held on Friday, April 22 and Saturday, April 23, at the Hotel Sheraton in Springfield, Mass.

W. H. Sharp, Pratt & Whitney Aircraft Co., East Hartford, Conn., will be Chairman of the Papers Committee. A plant trip is planned for Friday morning with a technical session in the afternoon. The Friday activities will be completed with a dinner that evening. On Saturday morning there will be a seminar. The New England Regional Conferences have already become highly known for the quality of their Saturday morning seminars.

Hotel reservations should be made directly with the Springfield hotel of your choice. For further information contact George P. Swift, Waltham, Mass.; John A. Swift, Hartford, Conn.; W. S. Mounce, Hartford, Conn; Howard E. Boyer, in Springfield, Mass., Mr. Malcolm or Mr. Sharp.



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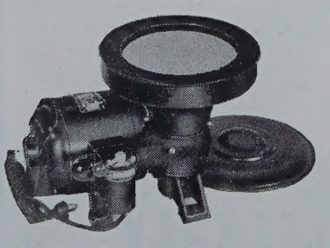

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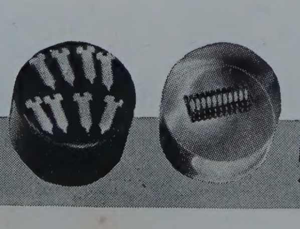

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## AIME at Western Metal Congress

The Metals Branch, AIME, will take active part in the Western Metal Congress at Shrine Convention Hall, Los Angeles, April 11-15, James A. Kavenaugh, Revere Copper & Brass Co., Los Angeles, having been appointed chairman for participation by this group. He will line up technical speakers for AIME technical sessions and was appointed by Harold J. Clark, Conservation Committee of California Oil Producers and chairman, Southern California AIME Section and by Dr. Leo Schapiro, Douglas Aircraft, chairman, Southern California Section, AIME Metals Branch.

This group will hold four technical sessions on the afternoons of April 11 and 12 and the morning and afternoon of April 14. The morning sessions will be held at the Biltmore Hotel. Simultaneously, and on other afternoons and nights, technical sessions will be given by the American Society for Metals, American Welding Society and American Foundrymen's Society.

At the Western Metal Congress special attention will be paid to metals for use in the oil, chemical, general manufacturing, aviation and mining industries. Newest developments in producing, fabricating and applying ferrous and non-ferrous metals will be described at the technical sessions. Authoritative speakers from all parts of the United States will deliver papers.

Displays and exhibits will demonstrate what is new and improved in metals, metal-working equipment and processes. Among the exhibits are those that deal with ferrous and non-ferrous metals, welding supplies and accessories, heat-treating equipment, foundry supplies, inspection equipment, materials handling and metal cutting.

Besides the societies already mentioned as participating are: American Chemical Society, Society for Non-Destructive Testing, American Institute of Electrical Engineers, American Petroleum Institute, American Society of Civil Engineers, American Society of Mechanical Engineers, American Society for Testing Materials, American Society of Tool Engineers, Pacific Coast Electrical Assn., Pacific Coast Gas Assn., Purchasing Agents Assn., Society of Automotive Engineers, Western Oil and Gas Assn., and others.

A local general committee is headed by E. R. Babylon, Kaiser Co.

JOURNAL OF
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## GUEST EDITORIAL

**ROBERT G. PAGE** • PRESIDENT, PHELPS DODGE CORP.

# *THE PLANNED ECONOMY*

It is a commonplace that the American system is on trial today. Here, at home, the system is under attack from two sides.

First, there are those who believe honestly that state socialism in some form holds a better future for the people. We like to think that relatively few people in this country hold such views. Perhaps the number is greater than we know. And there are not only those who would welcome a socialist state for the promise it holds out; to them must be added the greater number who, with some regret, now regard a socialist state as an inevitable end product of an irresistible evolutionary process which began not many years ago but which is moving fast.

To that group what can we say? Space here is insufficient to do more than suggest an outline. The superior material accomplishments of the American system have often been stressed. Is it not equally important that, without economic freedom, there will in the long run cease to be political, religious or artistic freedom? The completely planned society cannot tolerate individual action, and if it cannot tolerate individual action it cannot long tolerate individual expression of thought.

If that is so, it must be erroneous to assume that evolution is working inevitably toward a socialist state. The history of civilized man is largely the story of an advance toward freedom of the individual, of growing independence of man from control by the state. Any system which would again subordinate the individual wholly to the state represents reaction, not progress; and any view that development along such lines represents an inevitable evolutionary process disregards hundreds or thousands of years of history.

No form of society can stand still. Our system is a dynamic institution capable of great progress. Materially, the standard of living, represented by real wages, has risen steadily; and doubtless will continue to rise. We have also gone far to insure political, religious, artistic freedom—surely not readily to be abandoned. We have gone far to protect minorities; surely our progress in that direction has not been stopped.

The second and perhaps more dangerous attack on the American system has its roots, in varying degrees, in impatience, ignorance and irresponsibility. We must not only have the millennium; we must have it tomorrow. So, while professing devotion to the American system, advocates of a quick better life for all would have us adopt measures inconsistent with the effective operation of the system. Economic incentives to work, to invention, and to the practical application of invention are an essential part of the American system. Another essential part is capital—capital saved and put to work—and without adequate incentives capital will not be saved or if saved will not be put to work.

Preservation or extension of those incentives, to the greatest possible extent, ought to be the ambition of believers in the American system. But too many either do not know, or do not care, to what extent they discourage the very things that make the system go.

Here a single example must suffice. Recently the Administration, viewing the present shortage of steel and relying on estimates as to future consumption, has proposed that the Government be given the power to enter the steel business. (One may recall that at the war's end the Government planners expected a big slump in steel and other heavy industries.) The proposal disregards the fact that the trend in steel is now fortunately toward a much better balanced supply and demand. More important, it disregards the fact that the steel industry has shown a constant growth and over any reasonable period has always been able to produce more than the country could consume. To enter the steel industry, the Government would necessarily use money raised by taxes—and taxes are already so high that it is difficult to save and unattractive to invest what money is saved. The inevitable result would be to make capital from private sources less available not only in steel but in other industries; prospective Government competition is not conducive toward risk taking. All this is proposed because the planners are in such a hurry that they are unwilling to give the economic system a chance to function effectively, as it always has.

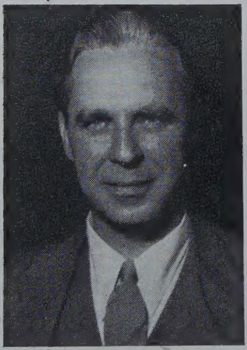
We must be alert to recognize and to oppose those proposals which seriously threaten the incentives which make the system work. But also we must refrain from attaching the tag "socialistic" to every effort to improve the lot of our citizens or to regulate excesses of economic individualism. Our "American system" is in a sense a mixed economy; it is already extensively regulated. The present trend seems to be in the direction of further regulation. The problem is the familiar one of drawing the right line—a problem which can never be wholly or exactly solved but which for that reason requires all the more attention and effort.

# Secondary Metals Increase in

### *U. S. Tends Towards "Have-Not" in Primary Metals*

The production of commercial alloy ingots by smelting and refining non-ferrous materials discarded by industrial and domestic sources has made notable progress during the twentieth century. Now tremendous quantities are reclaimed not only for producing commercial ingot metals, but also for the so-called primary or virgin metals.

Over two million tons of non-ferrous scrap metals are reprocessed each year and converted into useful engineering materials. Statistics indicate that currently more than a million tons of copper scrap processed by smelters reenter the metal working industry every year in the form of copper or copper base alloys, three times the quantity of 20 years ago. Again, the tonnage of these alloys which was returned to smelters for conversion into brass and bronze alloy ingots is currently over 300,000 tons per annum. Besides these, there are recovered many thousands of tons of lead, aluminum, zinc, and tin and their alloys.



**The author, Andrew Edmund St. John, was graduated in 1923 from Case Institute of Technology, following which he pursued studies in metallurgy and kindred subjects at Carnegie Institute of Technology, University of Pittsburgh and Columbia University.**

**Mr. St. John has been associated with the Federated Metals Div., American Smelting & Refining Co. since 1925 when he started his career with the company at its Pittsburgh plant. He has had a wide and varied experience with non-ferrous metals in production, sales and service engineering. In his present position he is responsible for the preparation of the many technical publications which Federated Metals has distributed to the non-ferrous metal working industry.**

**St. John is the author of a number of technical papers that have appeared in the trade press and is a member of A.I.M.E. and A.S.M.**

Foreign countries have made full use of their industrial scrap for many years because of the general shortage of non-ferrous metals in their countries. Not so long ago, the United States was exporting large quantities of such metals. However, the metal situation has been changed radically in this country and scrap metals are now in great demand. It is important for this country to utilize secondary materials as much as possible as we are rapidly becoming a "have not" nation in many metals.

Metal authorities are becoming alarmed at the rapid depletion of our copper, lead and zinc mines and it is estimated that many of these mines will not last more than one or two generations. Thus it is becoming more important to recover every ounce of metal which is discarded after a useful life and prepare for the time when most of our "mines" will be above ground.

Previous conceptions regarding so-called primary or virgin metals and secondary metals have also changed and today it is difficult to distinguish between the two. There is scarcely any metal produced in this country today that its not partly made up of secondary or scrap materials. Originally, the term "primary" indicated that the product was made solely from material mined from the earth. This is no longer true since "primary" smelters are dependent to a considerable extent on the use of secondary materials. In the steel industry, which is dependent to a large extent on the supply of scrap iron and steel, the terms "primary" and "secondary" have no application. It is well recognized by metallurgists today that the source of raw material is of no importance and the only "yardstick" is the composition and character of the finished material.

## early prejudices on secondaries

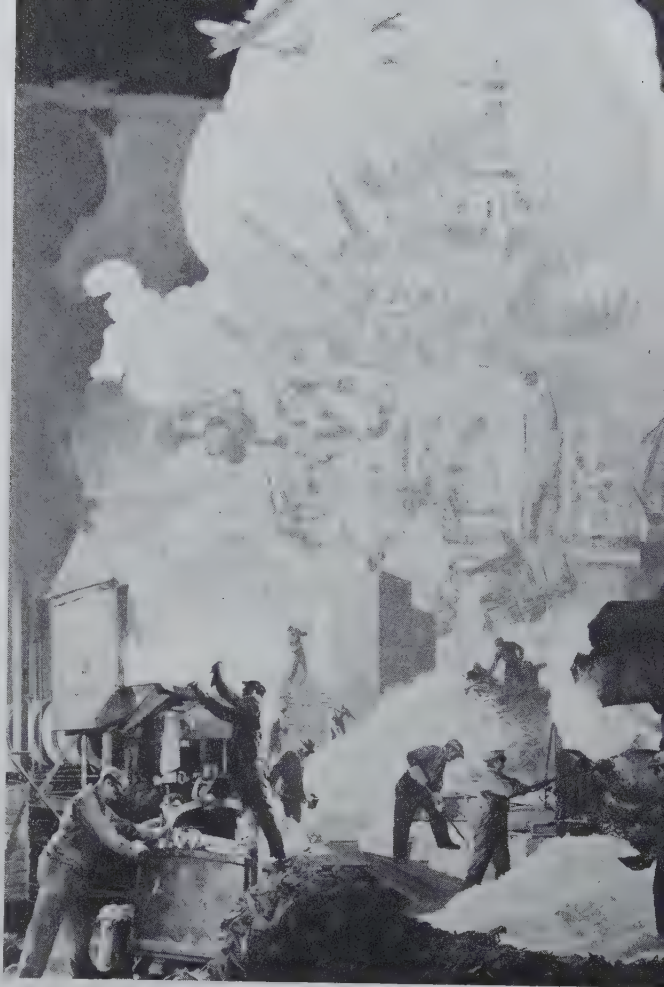
Until rather recently the use of secondary metals in a finished alloy was discouraged and deprecated because it was thought that the properties of the resulting alloys would suffer. Enough evidence has accumulated to discredit such theories so that in industries such as brass mills, scrap materials are considered an essential part of the charge.

Once there was a theory that metals lose "life" after repeated meltings, and occasionally this theory is still used in foundries to explain inferior castings. Many explanations, including the loss of "amorphous cement," were given to account for the apparent "death" of the metal. Today it is an accepted fact that a metal or alloy

# Importance

**A. E. ST. JOHN** • TECHNICAL ADVISOR,

FEDERATED METALS DIV., AMERICAN SMELTING & REFINING CO.



From painting by Ralph Iligan, nationally-known artist. In the foreground appear materials used in secondary metal production, with scrap in the immediate foreground. At the right, scrap is being charged into a furnace, while back of that proceeds the casting of ingots. In the left foreground is a container of ingots being picked up by crane for transportation to warehouse. Immediately behind this is a dryer for borings. In the upper half of the imaginative painting are the end products, the original idea having been for promoting our war effort—but the entire basic enterprise is equally applicable to peace.

*(Courtesy, Federated Metals Div., A. S. & R. Co.)*

can be melted any number of times without any change in quality providing there is no change in composition.

It was thought also that metals reclaimed from scrap would contain oxides and other foreign matter which would result in lower properties and limited usefulness. If this conception were true, then metals produced from ores would be far worse because ores very often contain only a small percentage of the metal, the balance being dirt, oxide, and other foreign matter. It is common today to mine ores containing less than 1% copper, leaving 99% foreign material which must be eliminated. By contrast, a piece of scrap copper or brass contains over 99% metal and should be, at least theoretically, far better than metal produced from ores.

Today the only criteria are the chemical composition and the mechanical and physical properties of the final product. World War II added impetus to the recovery of secondary metals because of the critical shortages. The Government formulated plans for the segregation of all kinds of metals in industrial plants, followed out carefully by most of the large metal working plants. This system has continued in force and this source of supply of raw materials has become a worth while contribution to the industry.

In the past, secondary metals were frowned on as standard engineering materials probably because of the conditions under which they were produced. Then very little scientific knowledge was applied in the processing. Mainly, the operation was one of segregating, blending, and remelting into the ingot form. Many empirical formulas were used some of which still prevail for those lacking scientific knowledge of the process. The color, the "feel" of the metal in the furnace, its viscosity, and many other such factors were used to determine the quality and character of the metal. Red brass meant almost anything that was red. The quantity of tin, lead, zinc, or copper could have varied considerably and still the alloy could have been passed off as red brass. In other alloys, the same routine. The expression "caveat emptor" well described the conditions under which commercial alloys were manufactured.

Today metals and alloys are well recognized as engineering materials by Government specifications and nationally known engineering societies such as A.S.T.M. and S.A.E. The key to the progress is the application of well known chemical and metallurgical laws in solving the problems in the various processes together with much scientific research. Now most of the key operating personnel are trained metallurgists or chemists. Scientific equipment and the latest methods are used to their fullest efficiency. All reputable smelters maintain research departments and service staffs so that those metals can be used for almost any application.

Typical of the progress are the plants of Federated Metals Div., American Smelting and Refining Co., who conduct one of the largest operations in this field on a national scale. Non-ferrous metals of all kinds are produced, including copper, tin, lead, zinc, aluminum, and nickel alloys in their many shapes and forms.

### segregation is important

One of the first important steps is the segregation of the scrap metals into groups and classifications, the extent being dictated largely by economic and metallurgical reasons. The industry has gone to great lengths to improve segregating the materials, elimination of rehandling, and to minimize the necessity for large storage spaces. Classification is called "sorting" and may depend on visual inspection, chemical, mechanical, or even spectographic devices. Classification is only preliminary and the final value and disposition of the material depends on an elaborate system of sampling and laboratory testing.

Copper base alloys lend themselves readily to segregation because of the significant colors shown by a bright fracture which vary from a coppery color to a yellow golden, depending on the copper and zinc content. In addition, many of the forms and shapes can be recognized as they are generally made of standard alloys.

Today, furnaces of as much as 150,000 lb. capacity are commonly used. Charges are prepared by the plant metallurgist and are combined and blended so that desired specification will be produced. Some adjustments must be made to the charge either because of the impurities or the major elements. Economy is an important consideration when calculating these charges in order to keep refining costs to a minimum.

Planned metallurgical procedures are used for eliminating such impurities as aluminum, manganese, silicon, phosphorus, iron, and sulphur. Antimony cannot be eliminated economically and when it is in excess of specifications the charge must be diluted so that its content will not exceed the specified tolerance. The percentage of elements such as copper, tin, lead, and zinc can be altered by dilution or addition and the zinc content can be reduced by volatilization. In each case the method used depends on the economical factors.

Frequent chemical tests are made of the charge while it is in the furnace and adjustments are made if necessary. Modern casting equipment is used and tests of the ingot are made at frequent intervals while being cast. Many types of casting machines are used such as straight line conveyors, rotating wheels, and overhead trolley systems. Sampling of the finished product follows a standard routine during the casting of the metal and after it is out of the furnace. Generally, these methods are based on A.S.T.M. sampling procedures.

### secondary aluminum prominent

The production of aluminum from scrap materials has increased spectacularly in a short time. The amount of aluminum used 50 years ago was practically negligible; in 1914, total production of secondary aluminum alloy ingot was under 5000 tons, against over 250,000 tons per year now. During the war it was over 350,000 tons per year. Besides, 100,000 tons of aluminum scrap finds its way back to the producer of primary alloys.

The progress in aluminum smelting and refining techniques has been much more rapid than in some of the other metals because metallurgy was already at an advanced stage when aluminum alloys met with great commercial demand. Hence, aluminum techniques are at an advanced stage. The secondary industry has kept up with the pace and done much original research, resulting in development of new alloys and changing many previous conceptions about aluminum, particularly as to elements designated as impurities. It is well known today that many so-called impurities are actually beneficial. The increased acceptance of refined alloy ingots can be observed by noting the changes taking place in the last few years in Government specifications for aluminum casting alloys and the elimination of sections of specifications which required the use of so-called primary aluminum in aircraft and other military applications.

The smelting and refining of aluminum alloys is limited because most impurities contained in them have lower oxidation values than pure aluminum. Hence, oxidation procedures, such as employed with copper base alloys, cannot be used because of the high affinity of aluminum for oxygen. Alteration of the quantities of impurities in aluminum alloys must be done by dilution, hence, it is necessary for the smelter to have a great variety of stocks on hand. The source of scrap is much more important in this field than in some others. There are methods available for eliminating certain impurities, but so far costs are prohibitive.

### procedures are similar

Procedures similar to those for other metals are followed in segregating aluminum scrap, because most of the aluminum alloys are similar in appearance and fractures do not vary enough. Fortunately, many of the wrought, rolled, or extruded products are stamped with identification numbers. Chemical and spectrographic tests lend themselves to rapid determinations because in many cases the identification of the quantity of a single element in the alloy is enough to indicate its general composition. Large tonnages of borings are generally used in the industry and sampling and classification of such materials are based on large samples which are melted down under fluxes and then analyzed by routine methods. In some cases, a 100 per cent sample of the borings may be taken.

The production of aluminum alloys by the secondary smelters of specification ingot at a minimum cost depends to a considerable extent on furnace practices much more so than with other alloys. Elements, such as iron, which cannot be eliminated by refining, can be kept to a minimum by appropriate procedures or by the previous removal of free iron materials manually or mechanically. Iron has a high affinity for aluminum and if not removed from the furnace quickly, will be dissolved and result in an ingot above the maximum tolerance for iron. Thus, one of the important considerations is to keep out of the furnace undesirable elements.

Not so long ago a furnace holding a charge of 10,000 pounds was considered to be quite large; today, capacities of 75,000 pounds are quite common.

Methods of sampling during melting and casting are similar to those employed in the smelting of copper base alloys. Casting methods have also followed a similar pattern, except that many smelters now prepare the ingots for shipment on standard pallet forms. In some cases special ingots are cast which act as a pallet suitable for handling by fork truck.

### scrap goes into white metals

Another group containing large quantities of scrap are white metals, comprising the series of alloys having a lead or tin base, generally containing antimony. Principal products are lead, antimonial lead, battery lead, tin-lead solder, tin and lead base babbitts, and type metals.

Lead and lead alloys produced by secondary smelters account for more than 350,000 tons per annum, representing over 30 per cent of the domestic production. Defunct storage batteries and lead cable account for more than half of the scrap accumulated in this category. The balance is made up of such metals as babbitt, solder, and type metals. The manufacture of type metals is dependent almost entirely on scrap metal, drosses, and residues.

The smelting and refining of white metals is somewhat different from copper or aluminum base alloys. Smelting is done on a larger scale than with other alloys because much scrap is in the form of residues and true smelting is involved. This is done in refractory lined reverberatory furnaces which generally produce an intermediate product, process metal. The refining of this intermediate product is usually carried out in kettles with capacity of as much as 200 tons. In smelting, oxides are converted into metal and the elimination of impurities or the adjustment of the final composition is made in the kettle.

Because of similarity in the looks of white metals, classification and segregation are more difficult than other alloys, yet much of the scrap is in the form of drosses or residues and no simple methods of classification are feasible, classification revolving around careful and accurate methods of sampling and assaying. In preparing furnace charges, blending various lots of metals is practiced so that smelting and refining costs are economical.

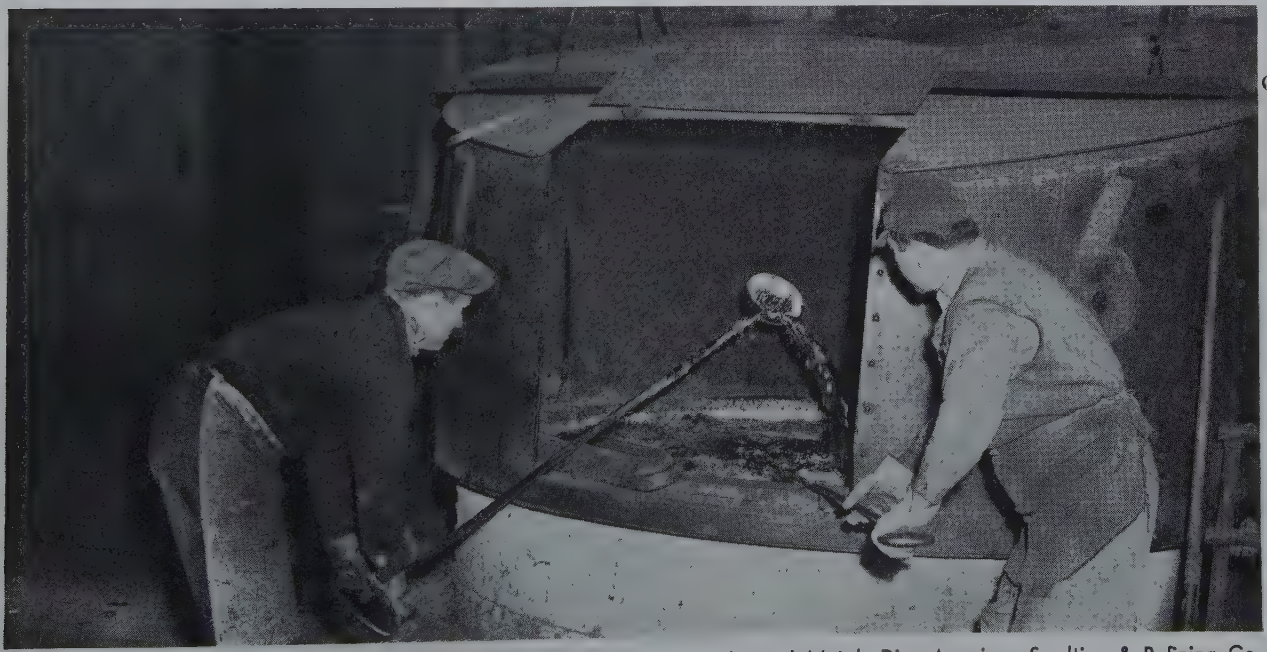
In the making of solders and babbitts, much raw material comes from drosses and residues. Currently, about 90,000 tons of solder is manufactured per year, hence very little primary metal is necessary.

### zinc industry uses much scrap

The zinc industry also uses large quantities of scrap, in the form of either solid material or residues and drosses. Galvanizers, brass mills, and die casters are the largest consumers of zinc. Current recovery of secondary zinc is around 300,000 tons per year which includes remelted or redistilled zinc or zinc dust or alloys containing zinc.

Die casting requires a zinc of special purity and no scrap is used. Zinc scrap generated by the die casting industry generally finds its way to the zinc smelters or to the manufacturers of alloy ingot who use it to recover the zinc in alloys where the aluminum content is not harmful. Considerable tonnage of zinc is also recovered from fume and flue dust which are generated by the metal working industry. A large portion of this tonnage is sold in the form of oxide and finds its way into the manufacture of pigments and paints.

The products of the secondary smelters are largely in the form of prime western grade zinc and zinc dust. The latter is used extensively in the chemical industry, primarily as a reducing agent. Prime western zinc returns to the galvanizing industry.



Twenty-ton refining kettle for white metals at Newark, N. J., plant of Federated Metals Div., American Smelting & Refining Co.

## Open Hearth, Blast Furnace April Meetings

The National Open Hearth Steel Committee and the Blast Furnace, Coke Oven and Raw Materials Committee. AIME, will hold their thirty-second annual conference at the Palmer House, Chicago, April 18-20. Invited to attend are all operating, repair and maintenance men, metallurgists, ceramic and refractory engineers, observers and any others interested in the production of more, better and cheaper steel and in problems connected with the reduction of iron ore in the blast furnace.

Besides the usual formal technical sessions trips will be taken through the Gary plant of the Carnegie-Illinois Steel Corp. on April 18. The trip's duration is about two hours, following which a luncheon will be served, courtesy of the host company.

The Conference will get down to business in earnest on April 19. At the open hearth program that day the McKune award paper will feature the General Session, Acid and Basic. At the Basic Session on Operations, ousting of sulphur will be discussed. At the session on Acid Open Hearth Operations topics will be metal fluidity, late ore additions, identical practice for ingots and castings, foaming ladle slags and carbon drop. At the afternoon Basic Session the topics will be oxygen and compressed air, factors of production, oxygen in waste gases, scrap quality, labor saving, blown metal and safety. The other afternoon session is on Cold Metal Operations and Basic Foundry Practice, where consideration will be given to scrap preparation, furnace design for cold metal shops, oxygen and compressed air, multiple burners, and bath temperature pyrometer.

A joint undertaking on the night of April 19 will be the Annual Fellowship Dinner, the speaker to be C. D. Randall, assistant to the president, Inland Steel Co.

The Open Hearth Committee will hold three technical sessions on April 20. At the Refractories and Masonry Session topics will be the basic-lined furnace, rammed and special brick mixer linings and silica versus basic brick. A simultaneous session on Metallurgy of the Open Hearth Process, will give some consideration to deoxidation practice for killed, etc., steels and the mechanism of foaming. At the Quality Session in the afternoon topics will include hot top designs, mechanically-capped ingots, oxygen injections, nitrogen compounds and residuals and other factors affecting surface quality.

### blast furnace program

At the General Session of the Blast Furnace, Coke Oven and Raw Materials Committee opening the day of April 19, the points to be considered are coke stability and furnace operation, reducing coal expansion pressure, and new equipment for recovering ammonium sulphate. At the Operating Session early that afternoon the one topic will be the operating differences between large and small furnaces, while at a simultaneous Coke Plant Session will be discussed rehabilitation of coke ovens. A reception will be held at 6:15 p.m. The Fellowship Dinner will be held at 7:00 p.m., as mentioned previously.

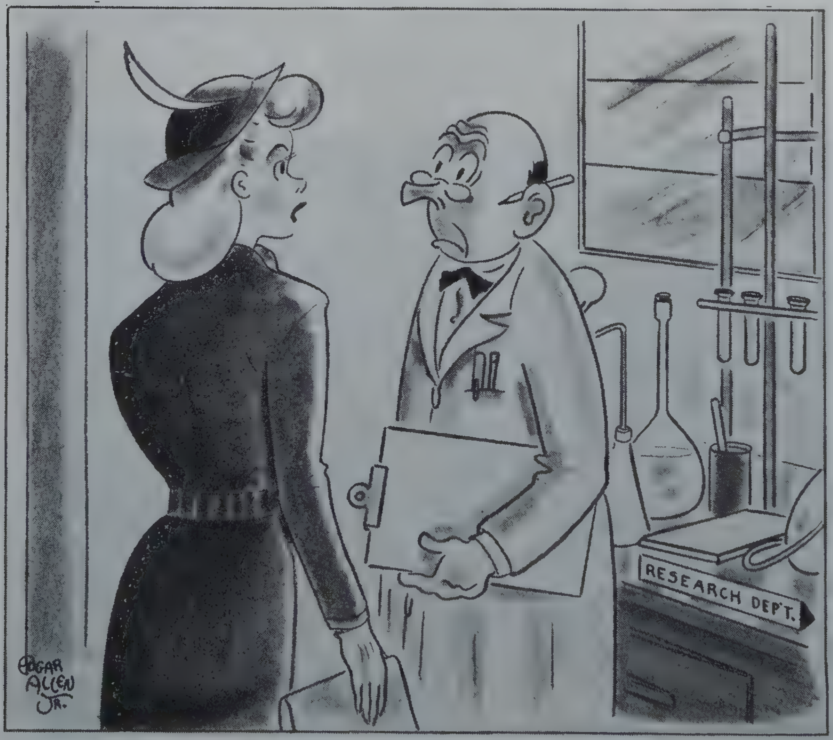
At the opening of activities on April 20 will be an Agglomerating Session, considering the following points: Manufacture of nodules, with fine ore and limestone, Mesabi fines and blast furnace flue dust; producing iron sinter with fine flotation sulphides and briquetting practice on fine ores. At the middle of the day will be held a luncheon and annual business meeting, to which all are invited. In the early afternoon a Blending Session will be held, describing operations at Geneva Steel and elsewhere.

For the trip through the plant of the Carnegie-Illinois Steel Corp. registrants will leave downtown Chicago by train every half hour from 9:00 to 11:00 a.m., inclusive, Sunday arrival being recommended for those who wish to make the plant trip. Hotel reservations should be made by writing hotels directly, mentioning specifically the Open Hearth and Blast Furnace conferences and time of contemplated arrival.

Registration fees are $6 for the Open Hearth and $5 for the Blast Furnace sessions. The Tuesday evening Fellowship Dinner will be assessed at $8.

## SMELTS and SMILES

By Edgar Allen, Jr.


RESEARCH DEPT.
EDGAR ALLEN JR.

"Oh, I know you get magnesium from the sea—but what kind of bait do you use?"

## Kieffer on Tungsten-Free Hard Metals

More than two years ago, at a meeting of the Powder Metallurgy Committee of the A.I.M.E., the suggestion was made to hold regional meetings of powder metallurgists to further exchange of ideas and promote friendship among people active in the field. Inspired by this idea, a dinner meeting was arranged on December 15, 1948, and invitations were sent out to all companies, schools and individuals within easy traveling distance of New York. The response was excellent and 54 attended the meeting despite a heavy snowfall that night.

A feature of the meeting was a talk by Dr. Richard Kieffer of Metallwerk Plansee, Reutte, Tirol, well known in this country as the author of two books and many publications on powder metallurgy. His subject was "Tungsten-Free Hard Metals." Some of the highlights were:

Whereas some attempts were made to eliminate carbides and switch to such compounds as nitrides, silicides, borides and oxides, the more promising approach appears to be the replacement of tungsten carbide by carbides of other high melting metals such as vanadium, columbium, tantalum, titanium, zirconium, chromium and molybdenum. Classifying such carbides according to hardness, titanium carbide tops the list. In general, the hardness values of carbides of the fourth and fifth group decrease with increasing atomic numbers. The reverse is true with carbides of the sixth group. Hardness alone however is of no value unless good strength can also be produced. This combination was found particularly in cemented columbium carbide, whereas molybdenum carbide and tantulum carbide are comparatively soft and not very strong.

Of more importance than pure carbides are solid solutions of two or more carbides. The first commercial material of this type was produced in 1930, consisting of titanium carbide—molybdenum carbide—nickel. With 55 to 80 per cent titanium carbide the hardness of this system tends to exceed that of technical sintered tungsten carbide. However, it is inferior in strength. Other double carbides were also described as to their characteristics and applications. Besides cutting tests, wear was explored by sand blast experiments. Ternary and quaternary compound systems have not been studied on a large scale. Here again the importance of solid solutions was made clear. An example of this type of composition was: 53 per cent titanium carbide, 20 per cent vanadium carbide, 10 per cent columbium carbide, 5 per cent molybdenum carbide, 12 per cent binder metal. By cold pressing and sintering hardnesses up to 91 to 92 Rockwell A and transverse rupture strength values of 130,000 to 150,000 psi were reached.

It was decided to hold another meeting on Wednesday, March 16. At that time it is planned to have a review of papers presented at the Powder Metallurgy Symposium in San Francisco at the annual meeting of A.I.M.E.

R. P. Seelig

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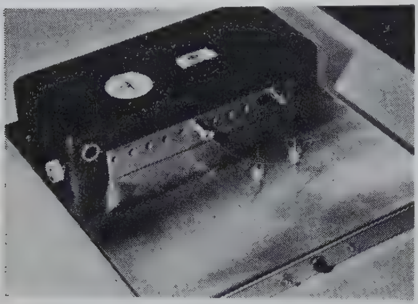
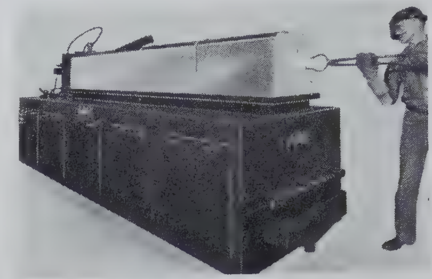
### Wire Fatigue Testing Machine

An entirely new development in rotating-beam fatigue testing machine for wire is announced by Hunter Spring Co., Lansdale, Pa., who claims that it will test to within 1 per cent error and with greater speed than heretofore obtainable. Its design involves looping a sample of predetermined length through a complete 180 deg. so that the bending stress can be predicted perfectly, simply calculated and brought to as great a value as desired to hasten specimen failure. It is adaptable to wire, 0.005 to 0.030 in. diam. With each tester comes two bushings (for magnetic and non-magnetic material) and a tool to cut the sample at the proper length and bend.



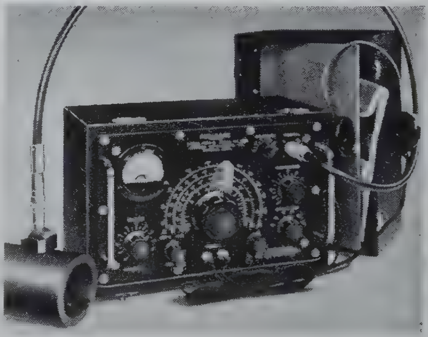


### New Induction Heater

A new induction heater delivers a steel forging blank to the mouth of the forging machine at a closely-controlled 2200 F every 4.8 seconds, or 750 forging blanks per hour. Made by Ajax Electrothermic Corp., Trenton 5, N. J., it permits the operator to flip the billets into the dies without extra steps or conveyor systems, heating so fast there is but little time for scale to form. The maker claims that it reduces rejects, permits cleaner, more precise forgings and reduces "down time" necessary to clean out dies. The heater in the accompanying photograph will accommodate square or round billets up to 2½ in. diam. Power source is a 700 kw., 960 cycle motor generator unit, with 100 kw. held in reserve.

### Thickness Detector

Non-destructive thickness measurement of steel, copper, aluminum, glass, unfilled plastics and other materials, made from one side, is obtained by a new model of the "Audigage" thickness detector made by Branson Instruments, Inc., Danbury, Conn. It is a new model with several improvements. Typical applications include tanks, pipes, ship hulls, boilers, pressure vessels and sheet metal. The machine generates ultrasonic waves, which are transmitted into the material under test, the instrument being tuned to a frequency which produces resonance in the unknown thickness.



### Manufacturers' Publications

"Wire Rope is a Machine" is the title of a new pocket-size handbook recently published by the Jones & Laughlin Steel Corp., Pittsburgh, Pa., designed to give men on the job an unusually simple and straightforward explanation of how wire rope works, how it should be operated and how to select and order correct wire rope construction for long service life on the job. "To demonstrate the facts of life about wire rope, small characters representing animated pieces of wire rope are used in the illustrations."

The Burrell Technical Supply Co., 1942 Fifth Ave., Pittsburgh 19, states that the copy of its "Announcer," designated No. 49-1-33, is the last that the company will distribute in the current form. The publication has been completely redesigned, the first to appear as a spring issue. Since the magazine contains articles and information pertaining to scientific advances and equipment, the company prefers to send it to business addresses.

Buehler, Ltd., 165 W. Wacker Drive, Chicago 1, has just published a bulletin featuring AB Surfacers and Grinders, which are in the class of specimen preparation equipment for the metallurgical laboratory.

The Dillon Universal Tester is described in a 4-page bulletin of W. C. Dillon & Co., Inc., 5410 W. Harrison St., Chicago 44. The machine will test materials with a tensile strength varying from only a few pounds to 160,000 p.s.i. Among the types of tests permitted are: Compression, transverse and shear.

"Applications and Properties of Nonferrous Powder Parts" is the title of a brief booklet of the New Jersey Zinc Co., 160 Front St., New York 7. Good and bad qualities of the various metal powders are described. Thus copper powders, being spherical are difficult to compact; zinc powders are irregular, but difficult to sinter. Tables of properties and characteristics are given.

### Men of Industry

R. S. Reynolds, Jr., president, Reynolds Metals Co., has been elected president of the Aluminum Assn. for the ensuing year. Elected vice presidents were: E. G. Grundstrom, Advance Aluminum Castings Corp.; M. E. Rosenthal, United Smelting & Aluminum Co., Inc., and George N. Wright, John Harsch Bronze & Foundry Co. A. V. Davis, Aluminum Co. of America, was re-elected chairman of the board, and Donald M. White was reappointed secretary and treasurer.

Robert G. Allen, Cohasset, Mass., has been elected vice president in charge of the Great Lakes Carbon Corp.'s Electrode Div., having been formerly manager of the division. He will make his headquarters at the corporation's Niagara Falls plant. During the late war he was in charge of engineering and production of light to heavy tanks manufactured along the Atlantic seaboard, later being transferred to field service with the rank of lieutenant colonel. He was with Walworth and Baldwin.

# BOOK REVIEWS

## Crystal Structures

*By R. W. G. Wyckoff, about* 600 *pages, Interscience Publishers, Inc.* $8.00.

Reviewed by Don M. McCutcheon

The principal foreign-source of information on Crystal Structures is no longer available which has undoubtedly influenced the release of this new ultramodern edition by Dr. Wyckoff.

The new edition eliminates the section on x-ray diffraction theory and interpretation which occupied a good portion of the 1931 edition. This is warranted because of the availability of other published texts where the subject is fully treated. Subject-matter is written in a lucid, conversational style, and is well supported by numerous tables, bibliography, and excellent half-tone illustrations of crystal arrangements. The Publisher points out: "That it is Dr. Wyckoff's intention to make this book an up to date archive and inventory of all known data and facts about crystal structures."

Published in loose-leaf form by the varitype process, Section I covers the crystal structures of the elements and inorganic compounds. Sections II and III will be published later for insertion in the original binder. Adoption of the loose-leaf construction allows the insertion of supplementary or replacement sheets as they are issued by the publisher, keeping the data up to date. The disadvantage of a loose-leaf construction is that a complete subject index is not possible. A scheme has been devised by careful arrangement of text material to aid in the search of a specific subject or compound. The success of this scheme rests with the reader and his willingness to spend a little extra effort in searching for a particular topic.

## Evaluation of Residual Stress

*By K. Heindhofer. McGraw-Hill Book Co.* 196 *p.* 1948, *Price* $4.00.

Reviewed by Dr. F. R. Morral

This small comprehensive treatise on residual stresses is a worthy addition to the Metallurgy and Metallurgical Engineering series. The author's purpose is to bring the subject up to date since the industrial application of the electric strain gauge, whose physical principle went unused for many years, since Lord Kelvin had reported it in 1859. Another purpose was to make this available as a textbook to graduate students of mechanical engineering and metallurgy, and to make it useful as a reference book.

The origin of residual stresses, and how the nature of metals limits stress analysis, is followed by chapters giving pertinent phases of the theory of elasticity and the critical representation of the data. Residual stress may be evaluated either by relieving the locked-up stress, or without doing it, when it can be measured either by X ray in opaque crystals or by polarized light in transparent media. A 1½ page treatment of qualitative and semi-quantitative methods is followed by 62 pages of quantitative methods. All three fundamental gauges for measuring stress are discussed: Mechanical, resistance and X ray diffraction. The latter only measures elastic strain and therefore permits discrimination between elastic and plastic strain.

In the last chapter several examples are given of experimental stress analysis and the interpretation of some of the results. The last 4½ pages contain a complete subject Index.

## Text on Science of Metals

*Introduction to Physics of Metals and Alloys. By Walter Boas. John Wiley & Sons, New York City. 1948. 193 p. $3.50.*

Reviewed by R. M. Brick and G. A. Moore

The contents of the book are best described by the section titles. Part A, Crystallography and X-ray Diffraction is brief but reasonably complete and well presented. Part B, Properties and Deformation of Metals, Single Crystals, and Polycrystalline Aggregates, contains a wealth of information not readily available from other sources and is the outstanding part of the book.

The typical deficiency is an unwillingness to clarify a brief statement. The author in discussing X-ray line broadening mentions the Gauss distribution curve and to understand the argument, most students would have to look up the original reference which, fortunately, is given. The author discusses Brillouin zones but they remain as hazy a concept as ever. Mott and Jones's book remains as the only source of real explanation of this recondite idea. Finally, some dogmatism appears as, for example, when the author flatly states that the basic concept of the mechanism of slip is the propagation of dislocations. The statement may be true for physicists but I doubt whether Dr. Hollomon, as well as many other metallurgists, would concede the dogma.

Despite these few imperfections, the book is a valuable contribution particularly to teachers giving undergraduate physics of metals courses. The college junior, having completed mathematics and physics, might well be introduced to scientific metallurgy by this book.

## Engineering Metals & Their Alloys

*C. H. Samans,* 913 *pp., the Macmillan Co.,* $7.50.

Reviewed by F. R. Morral

This book, printed very legibly and profusely illustrated with diagrams and photomicrographs and equipment, has enough material to present at least a two semester course to general engineering students who usually only are allowed one semester.

The first chapter discusses safety factors, gives an introduction to chemistry to permit more complete discussion of corrosion, and elaborates on physical properties of metals with emphasis on the mechanical ones. Chapters three to seven have to do with obtaining metals, pig iron, and some nonferrous metals, and the making of steel. Chapter 2 discusses pure metals and chapter seven the theory of alloys. Chapter nine on the principles of heat treatment is followed by a chapter on shaping and forming metallic materials. Chapters eleven and twelve discuss corrosion and protection of metals. Dr. Samans classifies his engineering metals from an application viewpoint into alloys used largely because of ease of fabrication, pipe, tubing and castings resistance to water corrosion, alloys resistance to chemical corrosion and the action of heat, alloys for application requiring high strength and toughness, and alloys resistant to general wear and operation, tool material, bearing alloys, and alloys used because of their special physical properties.

Chapters are started with an introductory statement giving the objective and is followed by general requirements, characteristics, specifications, special testing techniques, structure, fabrication, and type of alloys. Many alloys are mentioned by trade name. At the end of each chapter is a list of books and articles for further study; also publications of industrial concerns. On the last 26 pages the reviewer has spot-checked a complete index.

It is unfortunate that the concept of the $M_s$ temperature was not brought out by the author. The students understand it readily, while a statement such as that made on page 353 that martensite is formed at temperatures below about 350°F may be somewhat misleading, since the $M_s$ is considerably above that temperature for many steels.

With over a quarter of a million students in engineering, who at one time or another will be exposed to engineering metals, Dr. Samans's new approach to the subject should be welcomed.

### Common Sense in Steel Treating

*By W. R. Bennett, author and publisher, Brattleboro, Vt., 1948. 86 p., 7½ x 5¼ in., leather, $2.00.*

This small book is presented for the purpose of solving the difficulties constantly turning up in the daily life of the man whose duty it is to harden steel. It deals with specific problems causing trouble, points out dangerous steps and advises methods to eliminate them entirely, thus preventing the recurrence of similar situations.

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# 1948
# Annual Review

Generally speaking, the mining industry had a good year in 1948 with most mineral products being produced in record quantities for peacetime standards. The big boys—iron and steel, coal, and petroleum—indicated the industry-wide trend by surpassing 1947 production figures. Although exploration and expansion are being pushed aggressively in all branches of the industry, there is a pronounced trend to engineering and research directed at cutting production costs, improving the product, and finding new markets. These improvement campaigns are making headway; in the bituminous coal industry, 5.43 tons *per man employed* is the new production record; 83 million tons of iron ore were unloaded at lower Lake ports, breaking another peacetime record; magnesium, due to improvement in manufacturing techniques, now competes on the market with aluminum.

The discrepancy between demand and supply is beginning to ease, but copper was noticeably short. Approximately 50,000 tons of copper were lost last year by a strike at one mine. Demand will continue at high levels for a while because of Government stock piling (for which additional funds have been appropriated), continuing industry expansion, and shipments abroad, so pressure will remain on industry to maintain peak production, stake out additional reserves, and hold prices in check. Since these demands on industry are being heard most vociferously from Washington, it would seem that some assistance is in order in easing taxation on reserves and profits and equitable labor legislation.

One of our most forward-looking industries is the coal industry which is racking nerve and sinew to expand markets by research in synthetic fuels and combustion methods. By maintaining many scholarships and fellowships for students, it is expected that a steady stream of high-calibre personnel will be available for this research.

The decentralization of industry, which has begun for military reasons, may curtail the output in active coal producing areas but it may revitalize areas that have hitherto been far from markets.

Research in beneficiation, steelmaking, and nonferrous metallurgy is aimed at taking these processes out of the art-craft stage and putting them in the realm of applied science. Since the raw materials needed to supply industry must come more and more from large low-grade or more complex ore bodies, their utilization is dependent on the efficiency of these processes. Known reserves of many ores and minerals are greater now than they were before we entered World War II. However, the greatest exploration campaign in the history of the mining industry is now in progress. Geologists feel that new ore deposits will be found by the improvement and better understanding of existing methods of exploration rather than by the development of any new revolutionary technique.

In the following pages is a summary report of progress in all phases of the mineral industries, written by outstanding men who earn their daily bread and butter by pursuing their particular specialty in this basic field. It is the one chance in the year for every member of the AIME to learn the highlights of what is going on in fields other than his own.

# Mineral Economics . . .

## . . . dominated by political events; mining industry must educate public to a sound government policy

**BY ELMER W. PEHRSON** • CHAIRMAN, COMMITTEE ON MINERAL ECONOMICS, AIME

Political events, national and international, dominated the industrial scene in 1948, and their ultimate effects on the mineral economy of the United States are apt to be more significant than the advance in technology that the skill and imagination of the mineral professions can conjure up for some time to come. The outstanding development of the year was the Russian blockade of Berlin, established in April. This action, viewed in the light of experience of the last few years in Europe and in Asia, demonstrated convincingly that the peaceful utopia envisioned at the close of World War II is not for our time. Instead we must again prepare for a showdown with the forces of totalitarianism and conquest. It remains to be seen whether or not this conflict will be resolved by peaceful means.

The obvious need for shoring up our defenses focuses attention on several weak spots on the mineral front. We have been getting half of our metallurgical chromite and nearly a quarter of our manganese ore from Russia. The Bolshevist move in Berlin emphasizes our vulnerable position in these indispensable raw materials. United States resources are pitifully inadequate, as are those of the Western Hemisphere, particularly with respect to chromite. Bureau of Mines experts testified before Congress that the practicable utilization of low-grade domestic manganese deposits could be accomplished only by a flash of technologic genius. The fall of China into the Communist orbit which appears imminent, constitutes a threat to free access to the world's greatest source of tungsten and antimony, and places the tin, rubber, and other strategic materials we obtain from southeastern Asia in jeopardy. A glance at the world map is sufficient to indicate the hazards attached to dependence on India for strategic minerals and on the Near East for oil, and yet we derive much of our raw material from India, and Near East oil already is vital to Western Europe and may soon become important to the United States. Africa, perhaps the greatest storehouse of minerals that are deficient in the United States, presents a less serious strategic problem geographically, but with rapid advances being made in long-range bombing techniques, it is doubtful that mineral production and transport within the continent could be maintained at adequate levels in the event of war.

All this adds up to the conclusion that our mineral preparedness lags far behind our diplomatic commitments, a situation that calls for extraordinary effort on foreign procurement and on the search for and development of additional domestic resources as well as a more realistic recognition of the mineral facts of life. There are some who believe that the maintenance of the present boom and the prompt provision of adequate mineral defense can be accomplished simultaneously. They are calling for enormous increases in steelmaking capacity overnight, and referring to the immediate need for vast expansion of other raw-material supplies. Their views reflect an incredible faith in mathematical formulas. Those familiar with the problems and delays involved in expanding mineral production and the fact that our known reserves of many minerals already are being strained are skeptical of the expectation that Mother Nature will dance to the statisticians' tune even if government cracks the whip or essays the role of Lorelei in a golden stream

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of taxpayers' money for years to come.

The political campaign of the past year brought scant solace to the Cassandras of mineral depletion. The platforms of both parties gave meager recognition to this grave national problem. The election oratory failed to come to grips with the real issues. Candidates avowed their undying faith in the infallibility of American resources and their aversion to scarcities. The challenger brushed off the petroleum problem by facetious reference to the numerous agencies in Washington struggling with it. He dismissed the metal problem by calling attention to our "skimmed-milk" resources. He failed to note that America rose to power on the "cream" of its mineral resources, and that Hitler and Mussolini with disastrous consequences, resorted to "skimmed milk" in building their ersatz empires. To maintain its position in this competitive world, the United States must have raw materials equal to those available to other industrial nations. Unless we can make our submarginal resources economic through technologic progress, wisdom requires that we avoid using them. Artificial stimuli can be justified only in the interest of national security. Approaching exhaustion of the cream of our mineral resources is not a problem to be dismissed with a wisecrack.

Public indifference to the serious problems resulting from our mineral deficiencies was also indicated in the passage of the Stock-piling Act of 1946. At the close of the war we had on hand a sizable stock of strategic materials acquired at a tremendous cost. Memory of the harrowing wartime experiences with real and threatened shortages was still fresh. Yet our zeal for getting away from the privations of war, small as they were, and for putting chickens in pots and cars in garages caused us to dissipate much of our war-end defense inventory on postwar prosperity. The painful efforts required to replenish these stocks in 1948 when national security measures again became a vital necessity, suggest that a wiser course would have recognized that national preparedness is an indispensable and inseparable part of our new status in world affairs.

Space does not permit more detailed presentation of evidence of the lack of full appreciation and understanding in high places of the problems of mineral supply and of the fundamental importance of the mineral industries to the future welfare of the nation. Such appreciation and understanding is essential to the formulation of wise national policy and program. It can be fostered by those who know the problems best because of their expert knowledge and day-to-day contact with the production and use of minerals. These are the members of the mineral profession and they should become articulate in focusing public attention on the true contribution of minerals to our national well-being and the practical measures that are required to assure maintenance of adequate supplies in the future. Members of our profession thus have two jobs to do—one in the field, laboratory, mine, and smelter; the other in educating the populace as to sound government action required to protect it from the deprivations of possible future shortages of the sinews of abundant peace and of war. If we do less we are not fulfilling our full obligations as citizens of this great Nation.

## mineral production reaches new peak in 1948

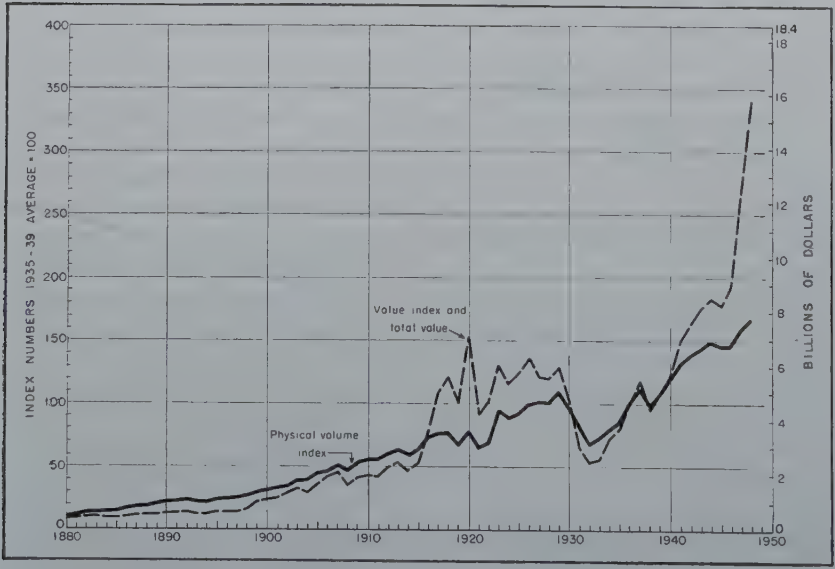
Passing to less provocative aspects of the mineral economy in 1948, it is a pleasure to record that mining enjoyed a prosperous year. Responding to the continued unprecedented demand, mineral production soared to record-breaking levels. The Bureau of Mines estimates the value of mineral output at $15,400,000,000, an increase of 26 per cent over the previous peak of $12,400,000,000 established in 1947.

The increase in dollar value in recent years obscures the true trend in the quantity of minerals produced owing to the sharp increases in prices. Nevertheless, on a physical volume basis, production of minerals in 1948 exceeded all previous records. The relationships between the dollar value and the physical volume of mineral production in the United States are shown in the accompanying chart on which is depicted the annual value and quantitative output in terms of index numbers based on the 1935-39 average equaling 100. The index scale is shown on the left side of the chart. The broken line representing the value index is also a record of the year-by-year dollar value when measured against the scale shown on the right side of the chart. The inflation of the World War I period and the boom of the 1920's is indicated by the gaps between the two lines. Likewise the deflation of the depression period of the 1930's is reflected in the value line falling below the physical volume line. The fact that the inflation in mineral prices resulting from World War II is far more pronounced than the situation in World War I, is clearly indicated by the enormous rise in the value index since the war in contrast to the modest increase in the physical volume index. Another characteristic emphasized by the trend line of physical volume, and one that has been alluded to previously, is that the quantity of minerals produced does not show spectacular advances except immediately following periods of recession. This phenomenon merely reflects the fact well known to mining engineers that the discovery and development of new mineral properties and the expansion of production capacity are time-consuming ventures. The rather stable trend, though persistently upward, should cause those planning revolutionary changes in industrial output overnight to consider carefully whether or not the supply of raw materials necessary to support their objectives will be forthcoming on schedule.

The mineral fuels always loom large in an over-all appraisal of mineral production, and the four per cent increase in the physical volume of total production in 1948 over 1947 is all the more remarkable when considered in the light of the five per cent decline in the production of bituminous coal. The effect of this decline on total output was more than offset by the increase in production of crude petroleum which gained eight per cent and that of natural gas which advanced ten per cent. One of the amazing aspects of modern life in the United States is the insatiable appetite of the population to consume liquid fuels. This persistent expansion in use is sorely taxing our capacity to produce so that during the last two years we have scarcely met our own needs domestically, whereas for several decades we had been a substantial net exporter of petroleum and petroleum products. The race between discovery and consumption has led some observers to suggest that the use of the fluid fuels should be restricted to those applications for which they are uniquely suited and that coal, by arbitrary acts of government, should be allowed to recapture its former markets lost to petroleum and gas. This conservation argument has some validity but the enforced substitution for reasons other than price and efficiency would inaugurate new concepts hostile to the traditional freedom that has prevailed in industry and in marketing and would constitute serious threats to the maintenance of a free-enterprise system.

The decline in bituminous coal production in 1948 as compared with 1947 was partly due to strikes but chiefly to a sharp reduction of exports of coal resulting from improved shipments from European-producing countries and to the abnormally mild weather prevailing in the latter part of the year. Preliminary estimates of anthracite production indicate only a slight decline from 1947. Prices for petroleum and bitmuinous coal declined in the latter part of 1948, and there are some who believe that a return to the cutthroat competition in the bituminous coal industry, similar to that which prevailed prior to the passage of the National Bituminous Coal Act some years ago, is underway.

Most of the metals were in short supply throughout 1948 and thus attracted major attention politically. Production of iron and steel ingots and castings was 3½ per cent higher than in 1947 and totaled 88,000,000 net tons. It undoubtedly would have equaled the 1944 peak of 89.6 million tons except for the coal strike in April which forced curtailment of steel production at some furnaces. Near the end of the year, the steel industry announced that its capacity was now 96 million tons per year with the expectation that it would increase to 98 million tons by the end of 1949. These figures compare with 80 million tons before World War II. A steady and substantial expansion in steel requirements for the United States in the years ahead certainly can be anticipated but it is believed that advancement will take place slowly. For one thing it is difficult to see how rapid expansion in pig-iron production can be achieved without colossal and time-consuming changes in our iron-ore industry. Some authorities believe that the iron-ore industry, due to transportation limitations and other restraining influences, would not have been able to stock sufficient ore at Lake ports during the shipping season in 1948 to assure full-scale steel production over the winter had not the steel industry been partly shut down by the coal strike last spring. A significant increase in steel production will require either expansion of domestic iron-ore production by initiating the large-scale use of low-grade taconites or by increasing imports. Major imports from Labrador are contingent on completion of the St. Lawrence seaway and present plans for that project would provide only a relatively small tonnage in terms of total need. Expanded use of Latin-American ores probably would require the construction of steel plants at seaboard since the use of imported ore at present inland locations probably is not economic. In any event, the problem of providing cargo ships for large-scale ocean movements would require considerable time. It is obvious that if rapid expansion of steel-making facilities is attempted the domestic economy must suffer in the meantime by the diversion of raw materials and equipment required in the construction of new facilities.



**Value and physical volume indexes** and the total dollar value of mineral production in the United States, 1880 to 1948.

Despite sharp increases in the prices of copper, lead, and zinc, domestic production of these basic nonferrous metals was lower in 1948 than in 1947. This decline in output can be largely ascribed to strikes which affected all three industries. Domestic production of aluminum surpassed all previous peacetime records and it now appears that the market for this light metal in the next few years will greatly exceed previous expectations. A large increase in output would have been required in 1948 to satisfy all demands, the chief limiting factor being the availability of electric power. Increased use of aluminum adds to our strategic material problem since the domestic industry depends to a large extent upon imported bauxite. The lower-grade deposits of the Caribbean islands are receiving considerable attention as an additional source of supply for the United States. Magnesium has not enjoyed the same boom as has aluminum and production in 1948 was restrained by the large quantities of scrap left over from wartime operations. Mine production of gold in the United States dropped five to ten per cent in 1948, chiefly as a result of the suspension of marginal operations caught between rising production costs and the fixed price for gold. Domestic mine production of silver declined despite the fact that it is again being bought by the Treasury at a price considerably above world markets. The adverse trend resulted from the curtailed by-product output at copper, lead, and zinc mines. Mercury production was hard hit during 1948, the output being 40 per cent below that of 1947 and the smallest since 1933. At the end of the year, the industry was virtually on a shutdown basis. Mercury mining has been seriously affected by rising costs and the sharp decline in prices following the close of the war. The present tariff of $19 per flask is insufficient to protect the domestic industry from the competition of the Spanish and Italian producers. Toward the end of the year it was apparent that price manipulations which had characterized the activities of the mercury cartel for years past were again coming into play. It was announced that a $14 increase in price would be effective immediately, but this action was not reflected in subsequent market transactions. A possible reason for the announcement was revealed a few days later when the Economic Cooperation Administration announced that it was negotiating for large-scale purchases of Italian mercury.

The nonmetallic metals were in strong demand during 1948 and all-time record shipments were made in sulphur, lime, salt, phosphate rock, potash, cement, gypsum, stone, kaolin, and others. The over-all value of the nonmetallic minerals produced in 1948 increased seven per cent, whereas the physical volume rose only five per cent. Price-wise the average advance for nonmetallic minerals was considerably less than that for metals and somewhat less than that for mineral fuels. Continued high levels of agricultural production and the favorable outlook for construction and industry in general indicate a further upward trend in the markets for these useful industrial materials.

## stock piling

The Government's stock-piling program made surprising progress in 1948. Despite the shortages prevailing in most of the strategic and critical raw materials, the Federal Bureau of Supply was able to make substantial cash purchases and commitments for forward deliveries. Total appropriations for stock piling made available on July 1, 1948 for expenditure in the fiscal year ending June 30, 1949, totaled 525 million dollars. In preceding years, 275 million dollars had been appropriated under the Strategic and Critical Stock-piling Act of 1946, so that a total of 800 million dollars has been authorized as of this time. All of the funds authorized for cash purchases and for contract authority had been obligated as of the end of 1948. Procurement has thus come virtually to a standstill and the President is requesting Congress to authorize more funds for procurement between now and July 1, 1949. The President's recent budget message to Congress indicated that 310 million dollars would be requested for this purpose. In addition, the regular budget for the fiscal year ending June 30, 1950 proposes another 525 million for new procurement. Should these recommendations be enacted into law, there will have been appropriated a total of $1,635,000,000 for stock piling under Public Law 520. In addition, the Government has on hand materials valued at 86 million dollars accumulated under the Stock-pile Act of 1939. Also, it is estimated that the surplus property remaining at the end of the war, which is to be transferred eventually to the permanent stock pile, will amount to 453 million dollars. All these items add to $2,174,000,000—the total stock-piling activity in sight at this time.

Elmer W. Pehrson

Those interested in funds available for Government procurement for this purpose might be confused with the manner in which Government budgeting is set forth. The 1950 budget book shows 564 million dollars recommended for cash purchases. This sum, however, includes 250 million dollars for liquidation of contracts previously authorized but not appropriated. This leaves only 314 million dollars for new cash purchases next year. In addition the budget book authorizes additional contract authority of 211 million dollars, making a total of new funds for stock-pile procurement of 525 million dollars.

The stock-piling program has been retarded by the provision in the law which states that so far as practicable purchases shall be made from supplies in excess of current industrial requirements. This has prevented the Government from competing with private buyers for available supplies. The restriction was relaxed early in the year by a directive from the White House to the Secretary of Commerce urging him to utilize the Voluntary Control Act, Public Law 395, as a means of diverting a larger proportion of current supplies into the stock piles without unduly aggravating inflationary pressures. As a result of this action the Secretary of Commerce, in October, held meetings with producers of copper, lead, and zinc. Up to this time the Government had been able to obtain but little of these metals for stock piles. At these meetings official procurement plans were laid before representatives from industry and an understanding was reached as to how the objectives were to be met. The producers indicated their reluctance to take collective action to reduce the quantity of materials available to consumers and indicated a preference for the Government to deal independently with individual suppliers. This was done, and late in December the Munitions Board reported that its procurement in this field was progressing successfully, and that the expected goals would be met on schedule.

Those interested in the stock-piling program should not be misled by current emphasis on completing the program in five years. At the present time, the objectives are being reviewed and the results to date indicate a considerable increase in the quantities to be acquired. Even the present minimum stock-pile objectives of some of the minerals cannot be obtained within a five-year period because available production facilities do not permit procurement at the rates required. When larger objectives are established, the time required to complete the stock-piling program will be even greater. In addition, there is a growing feeling that stock piling should take on a much broader aspect than the purely military one which now dominates the project. National security, both in peacetime and in war, is inextricably linked to adequate raw-material supplies. Therefore, as a matter of national security our stockpile program should be a continuous one, designed to assure adequate raw materials for the future.

### Interior Department seeks industry advice

Advisory councils established by the Secretary of the Interior have been mentioned in previous annual reviews. During the past year, the National Petroleum Advisory Council and the National Minerals Advisory Council continued to function and made several recommendations as to Government policy and current Government services in the mineral field. The National Bituminous Coal Advisory Council held its first meeting on Jan. 27, 1948. Apprehension as to whether or not this move constituted the first step toward Government control of the coal economy was indicated by some members. After full assurances from Secretary of the Interior, Julius A. Krug, that this definitely was not the case, the Council was formally organized on March 10 with Robert P. Koenig, president, Ayrshire Collieries Corp., as chairman. The Council participated in several policy matters during the year, including a substantial contribution to the Government's efforts to secure a voluntary allocation of steel for the mining-machinery industry.

A comprehensive review of 1948 should include discussion of a multiplicity of developments in the political field that have significant bearing on the mineral economy. Space permits only brief mention of a few. In appropriating funds for carrying out the Marshall Plan, Congress decreed that at least five per cent of all grants, after conversion into the currencies of the recipient countries, should be earmarked for the procurement of scarce materials for the United States. Results have been disappointing. ECA officials state that this type of program is difficult to administer and have presented a dim view as to the expectation of very large accomplishment. Early in December, Administrator Hoffman told the press that stock piling should be placed on a long-term procurement basis and established in a permanent agency of the Government. Such activity, of course, is already taking place on a large scale under the Stock-piling Act of 1946. National defense planning was stepped up considerably in 1948, with both the Munitions Board and the National Security Resources Board actively at work. Minerals command major attention in these programs. Announcement of additional negotiations on reciprocal trade agreements in 1949 forebodes further cuts in the mineral tariffs of the United States. Subsidy legislation failed of passage in the 80th Congress but a plethora of bills proposing various incentives to foster mineral production have been introduced in the 81st Congress. The Hoover Commission on Government reorganization made an intensive study of the mineral activities of the Government but there has been no public announcement indicating what recommendations will be made. These developments, plus the President's program as outlined in his State of the Union message to Congress in January 1949, make it clear that the mineral industries will again have a tremendous stake in and will be profoundly affected by events in Washington during the coming year.

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### Turkey Plans Development of Iron Ore Mines

The Turkish Government is now planning large-scale development of an iron ore mine at Divrigi, between Sivas and Erzerum, with the object of bolstering the raw material supply of the Karabuk iron and steel works. The Karabuk works have been operating at less than one-half capacity recently, 1946 figures showing that only 121,547 tons of iron ore had been sent to the two furnaces which have a capacity of 350,000 tons of pig iron per year.

The state-owned Eti Bank is cooperating with American ECA officials in working on the development plans, with their mutual aim an increase in Karabuk's pig iron output, thus enlarging Turkey's role in the Marshall Plan.

### Spectrum Used to Spot Silver

A method of determining the silver content of an ore or concentrate sample has been reported by the Bureau of Mines. Based on the spectrum range of radiations from burning chemical elements, the method consists of burning the ore samples in an electric arc and photographing the resulting colors.

The spectrochemical method is not as accurate as fire assaying, but it is satisfactory for determining silver content in field samples, and also reveals the presence of other metals simultaneously.

A free copy of the report on the spectrochemical method can be obtained from the Bureau of Mines, 4800 Forbes St., Pittsburgh, Pa.

### Southern Exposition Set for April

With the accent on higher production, lower costs, and all the latest equipment for achieving same, the Fourth Southern Machinery and Metals Exposition will open in the Atlanta Municipal Auditorium on April 25th. Meet the Future is the overall theme of the exposition, and more manufacturers than ever before will display their products during the three-day showing. Designed to stimulate the sale and distribution of industrial equipment throughout the South, the exposition also aims to modernize established industrial plants.

The Southern Industrial Conference on Machinery and Metals, sponsored by the Georgia Institute of Technology, will be held in conjunction with the exposition this year. Russell E. Bobbitt, Jr., is exposition president, and general chairman of the Industrial Conference is Dwight L. Hollowell, vice-president in charge of engineering at the Autosoler Co. in Atlanta.

# Mining Geology . . .

## . . . leads way in greatest exploration program in history

By **DONALD M. DAVIDSON** • VICE CHAIRMAN, MINING GEOLOGY COMMITTEE, AIME

Greatest in history is the pace and the scope of exploration and development now underway in the mining world. Never before in the industry have we seen such expansion of activity nor expenditure of such vast sums in the search for needed minerals. And, fortunately for this country, in the relatively short space of time since the end of the conflict, under the direction of mining geologists and engineers, we have re-established our metalliferous reserves to a point where, in many districts, the supply is equal to or even greater than were the reserves when we entered World War II. How did this happen? It happened primarily because nature has been indeed bounteous in her endowment of mineral deposits in the deeper reaches of the confines of this country. Hence, there could be a ready response to the intensive search in depth which has taken place in the last three years. It was only possible, too, because we live in a free economy which allowed us to react promptly to the lure of higher metal prices. And, finally, it was accomplished because the far-sighted, key men in the industry sent forth the challenge to geologist and mining engineer to find more ore and, most important, provided ample funds for the search.

The accomplishment of the past few years should answer pretty well the pros and cons as to whether we belong in the category of have or have-not nations so far as adequate ore reserves are concerned, but, for those who may still be skeptical, let them consider the proposition which few thinking mining geologists would deny, to wit: were it possible to strip off 500 feet of our country's surface we would, in all likelihood, encounter a vast number of great ore bodies heretofore unknown. Admiting this, then, the problem resolves itself into an appraisal of how much will be the cost and by what means shall we unearth these deep-lying ore bodies. Practically everyone agrees that hence forward it will be more expensive and take more time to find the ores necessary to support our economy efficiently. Not many will agree, however, as to the most effective methods and techniques to use in the search. The consensus seems to be that there is no easy way. In other words, no new startling developments either in geological or geophysical techniques will provide a facile answer to our problem. Rather, we must use the old tools which we have had long at hand. As Hulin has pointed out, these tools may need resharpening, but they are, no doubt, adequate for the job we have to do. Ore finding is fundamentally a geological problem. A successful approach to its solution can be stated no better than to use Levorsen's cogent words in appraising the similar quandary in oil; namely, that the answer to geological problems is simply —"more geology."

Donald M. Davidson

Probably a great stimulus will come from proper training of a new crop of geologists. In this connection, Broderick in his presidential address befor the Society of Economic Geologists raises a point of fundamental importance: do we really teach or train our students in the best possible manner in order to meet our present-day needs. All of us at times turn introspective, and many of us feel real frustration when confronted with the problems which lie ahead in connection with the enhancement of ore supplies. Our seats of learning are adequately supplied with first-rate text books. Our lecturers today, probably, number more competent men than ever before. Courses certainly are more elaborate and comprehensive and include more of the so-called basic sciences than was the custom even a generation ago. Yet, many of us question if, in spite of all this, somewhere, somehow along the line we are not missing the boat badly in our training of professional men. Imagination—that seems to be lacking. Broderick emphasizes the point and ponders ways and means to stimulate this all too rare quality. To state the problem is easy, to provide a solution, hard. Perhaps the matter can be advanced somewhat, however, by broadening our courses culturally and by seeking lecturers who are inspirational rather than purveyors of fact only. This thought has some backing when one considers history in the profession, for the record shows that a relatively few great inspirational teachers of the past generation—men like Kemp for instance—have turned out the lion's share of those who subsequently made real contributions to the science and the industry. Such gifted men are rare and must be diligently sought out to be put into positions where they can inspire the young. Fortunately, these days, salaries for those who live in the ivory towers of learning have increased to a point where they are competitive and serve to attract talent from the highest levels.

In speaking of education, one cannot pass without mentioning something of great importance, namely, that we do not properly impress students with the fact that mining is a business, and a tough one, and that in it one of the major, if not the paramount, factors in success is the ability to get along with one's fellow man. All of us in the industry know that a student's real education starts after he leaves school, and all of us know, too, that a most important part of that education is the successful adjustment of one's self to other personalities. Few men have risen to the top by sheer selfish force of wit and will alone, in utter disregard of the rights and feelings of fellow workers. Every executive knows these days that a business cannot be efficiently maintained unless personal relationships reach a high and satisfactory level. We must engender teamwork all along the line.

Most important, we should firmly implant in students the thought that the first place to commence a search for new ore bodies is in the reaches of the mind. A geologist is peculiarly well fitted to realize that since the advent of our species here below, the profound and significant changes which have transpired on earth have resulted only as the fruits of man's imagination.

## lead and zinc

When considering lead and zinc, one's attention is first held by what probably constitutes the world's greatest reserve, the Broken Hill district in Australia. Developments there, during the past few years, have been more than satisfactory from the standpoint of additional reserves which were made available through the geological perspicacity of the men who guided the exploration campaign. John Gustafson and his associates, chiefly Burrell and Garretty, must be highly credited for their share in the enterprise. The latest news from New Broken Hill Consolidated Mines is that, at nearly 3000 ft below surface, a drill hole indicated an intersection of 66 ft of better than 10 per cent lead and 11 per cent zinc ore, with the hole still in ore at latest reports.

Most absorbing are the recent developments at Tsumeb, Southwest Africa, now that the mine has been unwatered to the bottom level and a thousand-ton-per-day flotation mill put into operation. Drilling on the bottom level indicates a massive high-grade lead-zinc-copper ore body of such extent that it may well prove to be one of the world's great base-metal lodes. This company owns, as well, extensive ground which now is being prospected; some results are of more than passing interest. The same may be said for O'okiep Copper Co., South Africa, where a new substantial ore body may have been unearthed from testing a geophysical anomaly. The much publicized Mpanda deposit, Tanganyika, East Africa, appears to have fizzled out as far as a potential large supply of lead is concerned. The reserves of the Zellidja mine, French Morocco, are being considerably enhanced and the outlook this year is much improved over 1947. It is probable that this district will eventually provide an important source of lead.

At home, we are adding perceptibly to our lead-zinc reserves. John Brown writes of a zinc discovery of appreciable importance made in the vicinity of the Balmat mine in northern New York. He also relates that routine exploration in southeastern Missouri continues to reveal the normal complement of new reserves. Of special importance is a find in the Leadwood area, where an unusual occurrence lies in a zone of coarse boulders flanking a Pre-Cambrian knob.

Developments at Friedensville, Pa., by the New Jersey Zinc Co., will ultimately lead to the construction of one of the country's largest, most modern zinc concentrators. This Company, too, is carrying on extensive exploration near its properties in the southeastern zinc areas.

In the Wisconsin-Illinois district, developments are meeting with some success. Calumet Corp., a subsidiary of Calumet & Hecla, is now engaged in sinking a shaft near Shullsburg, Wis., following a successful exploration campaign under the direction of T. M. Broderick. The Eagle-Picher Co. has been fortunate in its testing of the area, having developed the Graham-Snider tract near Galena, Ill.

Prospecting in the Intermountain States also reveals increasing reserves. For instance, at Bingham, Utah, the U. S. Smelting Refining and Mining Co. is finding promising occurrences in their major development program and, according to R. N. Hunt, chief geologist, they can reasonably be expected to provide substantial production of lead-zinc-silver ores for a decade at least. The New Park mine near Park City is adding substantially to its reserves; and, in addition, seems to have made an important discovery of bedded-type deposits.

The Central mining district, N. Mex., gives promise of increasing both its reserves and production of zinc; the large contributors being Peru Mining Co., U. S. Smelting, AS&R, Empire Zinc, and Kennecott. Kennecott is now hoisting zinc ore through its new Oswaldo shaft at Chino. It will surprise some to learn that this district now ranks third as a zinc producer in the Western area. The Kokomo area, Colorado, promises to add to Western production. Here AS&R is exploiting rich leases discovered in recent years. The potentialities of this district are considerable. Combined Metals Co. continues to develop vigorously lead-silver-gold ores at Pioche, Nev., where results during recent years have put this area into a prominent place.

From the Coeur d'Alene district, Phil Shenon reports the spectacular discovery made by Hecla's Polaris and the Silver Summit from their jointly-owned shaft, where several important veins have been found, one of which has proved bonanza silver values. AS&R and Day Mines, Ltd., are also jointly engaged in testing a geological setting similar to the one just mentioned and as described by Shenon last year. These companies command admiration for their vision and courage in undertaking expensive major developments which hold promise for prolonging the life of the district for many years.

In the Metalline district, Wash., the Pend Oreille Co. is constructing a 2500-ton-per-day mill, and twenty miles to the north, in British Columbia, it controls the important Reeves-McDonald property, which ultimately plans a 1000-ton mill.

The development of phosphate deposits in Idaho is important. These reserves, which run into billions of tons, are being exploited by several companies, of which Anaconda is chief. By-products from phosphate ore include vanadium and fluorine, which, in consideration of the fact that the ore runs about 6 per cent of almost limitless reserves, justifies special consideration.

Canada provides news of important lead-zinc discoveries on Great Slave Lake, where Hollinger and Noranda interest are actively exploring new finds. Sherritt-Gordon has unearthed some promising zinc reserves in its recent developments.

While the production of lead and zinc from the British Isles is negligible, a nine-mile sea-level tunnel is being driven at Halkyn, North Wales, in which, according to Dunham, the prospects appear good.

### copper

Here at home major developments of prime importance are taking place. The bold and aggressive attack being made by Magma on the San Manuel deposit, Ariz., is commendable. The extent of the reserves are ten and, possibly, fifteen billion pounds of copper. Incidentally, some sort of record must have been established by one of the recent drill holes at San Manuel, which penetrated an unbroken stretch of 1700 ft of mineralization estimated at about 0.8 per cent copper and, when stopped, was still in sulphides.

The Greater Butte project insures the future of the Butte district as a major supplier of copper for decades to come. Painstaking yet large-scale checking of ore grade which was so exactingly carried out to insure the project's sound foundation is a feat of no little magnitude.

Not so much publicized, but, nevertheless, of considerable potential import, are developments undertaken by Copper Range at White Pine, Mich. Preliminary estimates indicate some 200 million tons of 1.1 per cent copper ore occurring in sandstones and shales. Calumet & Hecla has been active in the development of the Kearsarge-amygaloid. They are likewise testing their two more recent finds—the Iroquois amygaloid and the Houghton conglomerate ore bodies.

Abroad, there have been several outstanding developments during the year. Probably the most important are those in the Belgian Congo, where the ore body at Fungurume begins to shape up as one of the world's greatest in size as well as grade. In consideration of all geological factors, one may hazard a guess that the ultimate reserves of copper ore in the Katanga will place it as one of the world's foremost copper provinces. This year, again, the Northern Rhodesia mines are plagued by power shortages and inadequate railroad facilities. However, the Selection Trust group has resumed prospecting on a substantial scale after a hiatus of fifteen years and, in all likelihood, some important additions to known reserves will result. Frobisher, a subsidiary of Ventures, Ltd., continues its development of the Kilembe prospect in Uganda, a courageous undertaking characteristic of Thayer Lindslay.

In Canada, the major copper producers—Noranda, Hudson Bay, International Nickel, Falconbridge, Waite Amulet, and Sherritt-Gordon have all prospered. Noteworthy is the enlargement of the ore supply at Sherritt and especially the finding of a new ore body at Waite Amulet. East Sullivan has commenced a 2000-ton-per-day concentrator.

### nickel

In nickel, interesting developments are reported from Canada where Sherritt-Gordon is in the shaft-sinking stage at Lynn Lake. Several interesting discoveries were reported from this district during 1948. The *Northern Miner* reports that International Nickel has developed an oxidized nickel ore body in Venezuela of fifty million tons of 1¾ per cent ore, but, due to the difficulties of extraction, the matter is in the consideration stage for the time being. In Africa, a sizeable survey is underway which will embrace the famous Bushvelt-complex area. This is a justifiable enterprise, long overdue.

The Bradley Mining Co. is constructing a million-dollar smelter with a capacity of 6000 tons of antimony yearly, or approximately one third of our current annual needs, to treat antimony concentrates from Stibnite, Idaho.

The Lithium Corp. of America is exploiting, on a substantial scale, spodumene in pegmatites near Hill City in the Black Hills of South Dakota. With other chemical companies, it is aggressively exploring possibilities for the use of this light metal, although the demand for lithium is already on the increase. Reserves in the Black Hills appear to be adequate for some time, but the pegmatites in Manitoba, Quebec, and the southeastern United States are under scrutiny as sources of supply.

### gold

Large-scale developments in the Orange Free State, South Africa, far to the southwest of the producing areas, continue with vigor. More than

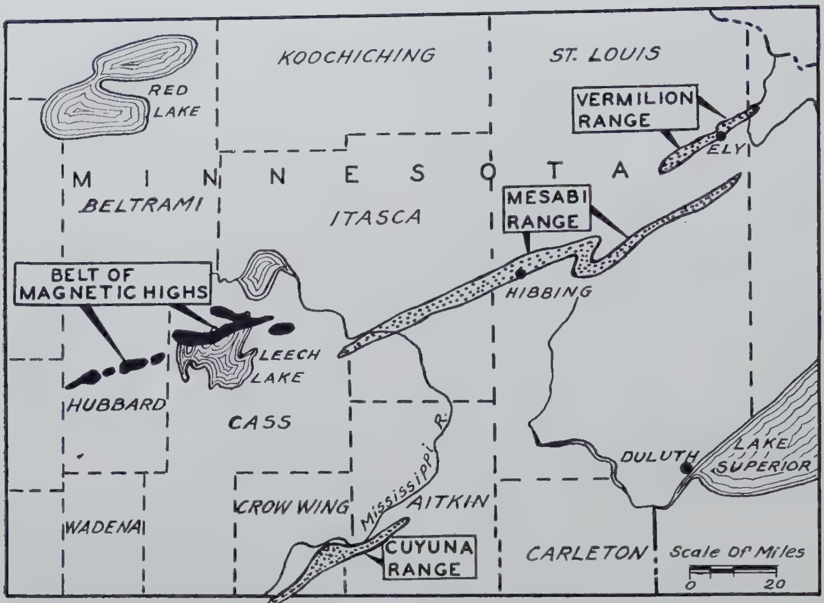

Fig. 1. **Magnetic highs,** as revealed by an aerial magnetometer survey by the United States and Minnesota Geological surveys in an area west of the iron producing country in Minnesota, are shown in black.

a dozen shafts are being sunk and large areas of ground are still being explored. The industry here is becoming well established, and American capital has entered the scene in quantity. In particular Blyvooruitzicht continues to develop in the Carbon Leader values which are, to say the least, phenomenal (60 dwt over 14 inches) both in gold content and in percentage of payability on reef development.

In Canada, as reported by Lionel Simard, there is now the feeling that costs have reached their peak and that time is on the side of the gold operators. While there are several new operations this year, these are not to be compared in number with boom years and, generally speaking, 1948 will be regarded as relatively dull by gold miners in the Dominion. On the whole, the big operators have increased their output to near capacity in spite of considerable handicaps; the largest increase being that of Kerr Addison, which jumped from 2250 to 4000 tons per day. The Canadian controlled Isles of Pines gold mine, just south of Cuba, tuned in a 100-ton mill which will treat better than half-ounce ore; thereby putting to shame the lighter minded who claimed that this property was to serve only as a winter resort for some of the "better heeled" members of the Canadian mining fraternity.

## Iron ore

In this country, the controversy concerning our reserves of high-grade and direct shipping ore will probably continue to wax and wane, largely because of the various points of view and lack of definition of terms and conditions. Regardless of this debate, both foreign and domestic reserves are being greatly enhanced. In Minnesota the value of unmined ore increased by 10 per cent over 1947. New discoveries total 53 million tons valued at $258,000,000.

In the Lake Superior district, prospecting generally is on a scale scarcely before witnessed, and is reminiscent of the activity which attended the original discoveries of the various ranges. The huge reserves and production in the Lake Superior area dwarf similar activities in this country, but developments in the Alabama field deserve notice as well as those in New York State, in Utah, and in Southern California. The total reserves in Iron County, Utah, may reach 350,000,000 long tons of ore which will run between 45 and 50 per cent iron. This reposes as a comfortable reserve for the Columbia Steel works at Geneva. Henry Kaiser's eagerly awaited Eagle Mountain deposit is now in production. It is a welcome addition to the West Coast industry and will help to balance the steel business nationally.

In northern Canada, the Hollinger-Hanna interests more than exceeded their minimum goal of 300,000,000 tons of high-grade iron ore which was the objective thought to be necessary to justify railway construction. Operations next year are expected to center on testing for new deposits rather than extension of tonnages from known ore bodies.

The Oliver Iron Mining Company's large undertaking in Venezuela has proved up tremendous deposits of high-grade iron reserves which probably can be freighted down the Orinoco River. Here is another example of vision coupled with courage which has successfully resulted in substantial additions to the world's iron ore resources. The project at El Pao, developed in recent years by Bethlehem Steel Co., is now reaching fruition and will soon be shipping ore on a major scale down the Orinoco River.

Quite recently, the Minnesota Geological Survey, coupled with the Federal Survey, has made public the results of an airborne magnetometer survey of ground to the west of the producing ranges in Minnesota. Although some of the anomalies in this area have been known for many years, nevertheless a few entirely new ones have been delineated while the whole picture has been refocused in a striking manner (Fig. 1). Probably the consensus among the mining fraternity in the Lake Superior district is that these anomalies may represent an extension of the Vermillion type of ore, but this is by no means certain. Regardless of the ultimate outcome, this survey represents a fine piece of work and those connected with it are to be commended for their efforts and should be encouraged to continue this sort of prospecting, which ultimately may result in welcome additions to the district's iron-ore supply.

The titanium development at Allard Lake is deservedly much to the fore this year. This great enterprise says much for the sagacity of Kennecott and the New Jersey Zinc Co. and will have a beneficial effect on the mineral industry of Canada. It will also alter, and probably for the better, the entire picture with regard to the titanium economy in North America and should free us at last from the domination of the Travancore, India, supply.

### aluminum

The development of aluminum ores in the Caribbean area by the major companies appears to assure the Western Hemisphere of a major source of high-grade ore supplies, although the treatment of some of these deposits presents problems differing from those attending the beneficiation of bauxite. Then, too, in Oregon and Washington, the Alcoa Mining Co. has developed colossal tonnages of lateritic aluminum reserves which can, no doubt, be used as a source of aluminum if circumstances should warrant.

### U. S. Geological Survey

The U. S. Geological Survey has in recent years earned a place approaching that which prevailed in the great days when it numbered on its rolls such masters as Lindgren, Ransom, Emmons, and others whose names are hallowed in the profession. We recognize, and with pride, that our Federal Survey is now composed of some of the strongest men in the profession and, comfortingly enough, this embraces the metalliferous branch which has to do with long-range plans for seeing that our vital metal needs are adequately surveyed. Under the wise and tactful direction of Doctor Wrather and his associates, the headway is great. During 1948, 82 field, laboratory, and report projects were executed, of which 24 dealt with base metals and fifteen with deposits of iron and ferroalloy minerals. One of the most concentrated efforts of this section were directed toward the uranium-vanadium deposits of the Colorado Plateau. Important advances have been made in the study of pegmatites which have contributed brilliantly to our knowledge of this type of mineral occurrence.

Research work on the development of geochemical methods for prospecting for ores continues in a large way, with emphasis on the study of zinc and copper, in ground water, soil, alluvium, and vegetation. This work will be expanded next year. With all this, considerable research is being carried on and the Survey contemplates an expanding program.

### uranium

From the standpoint of public welfare, the reserves of no other metal rank in importance with those of uranium, and no exploration program is as vital nationally as that now envisaged by the Atomic Energy Commission. In 1946, Congress, when establishing the Commission, instructed it "to conduct and enter into contracts for the conduct of exploratory operations—to determine the location, extent (and) mode of occurrence—of source materials." For this purpose, an advisory committee of prominent mining engineers and geologists was set up and John Kyle Gustafson was appointed director of the Division of Raw Materials for the Commission. He, with his capable assistants. has in hand one of the most aggressive, large-scale exploration campaigns witnessed in modern times. The exploration, which is being aided by the USGS, is devoted principally to the development of the carnotite-type ore in the Colorado Plateau region. Some measure of the magnitude of this undertaking is evidenced by Doctor Gustafson's recent remarks in stating that the AEC's schedule calls for several hundred thousand feet of drilling annually. However, in spite of the huge undertaking on its own account, the Commission ultimately hopes to turn over to private industry practically the whole job of supplying the AEC with uranium concentrates for processing.

In April, AEC announced a three-point program, the highlights of which are: first, a $10,000 bonus for the dis-

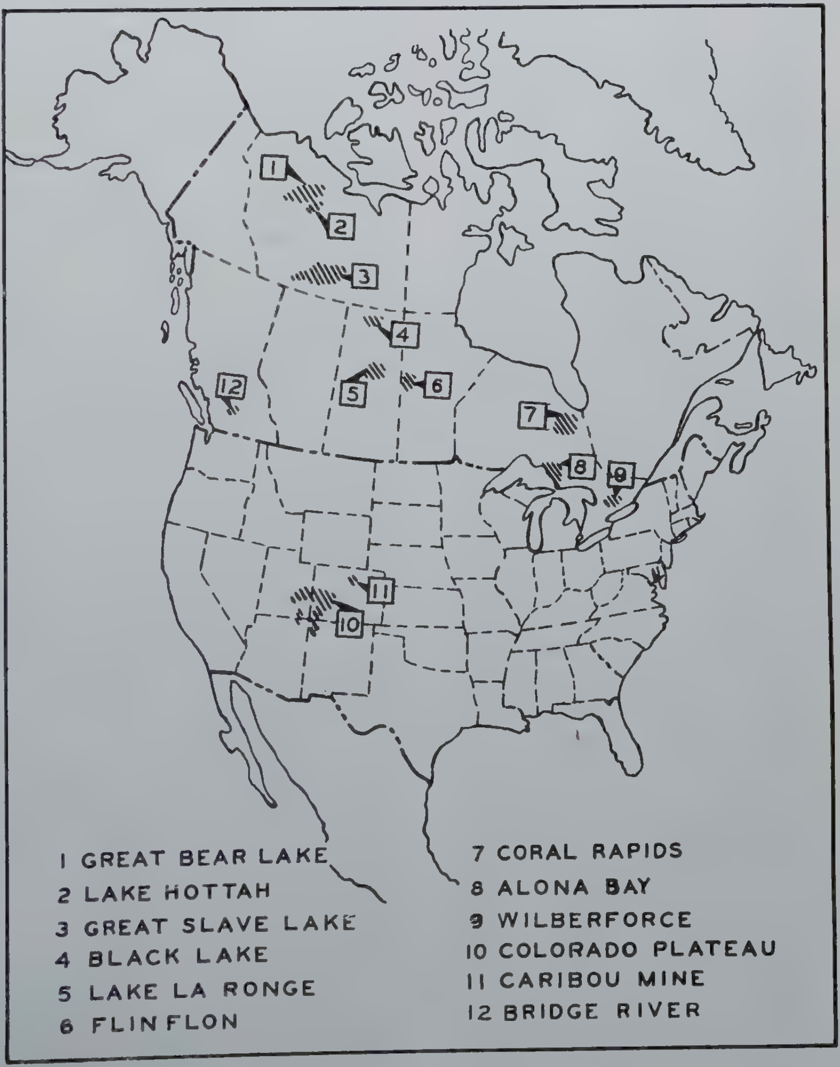

Fig. 2. **Uranium occurrences** in North America are shown by shading.

covery of a new deposit and production from it of twenty tons of uranium ore or concentrates assaying 20 per cent or more $U_3O_8$; and second, a guaranteed three-year minimum price for low-grade carnotite-type ore assaying 0.2 per cent. The price is $1.50 per lb of $U_3O_8$ plus bonuses and allowances which make the rate roughly equivalent to the Canadian minimum price of $2.75 per lb for ores or concentrates having at least 10 per cent $U_3O_8$. Payment is made, as well, for $V_2O_5$ content and an allowance of 6 cents per ton-mile is given for hauls up to 100 miles. Third, is a guaranteed ten-year minimum price of $3.50 per lb for all $U_3O_8$ for uranium ore or concentrates assaying at least 10 per cent $U_3O_8$.

These prices are attractive as evidenced by the mining operations now underway or planned. The Vanadium Corp. of America is reported about to undertake a large-scale stripping operation at La Veta Pass, 22 miles west of Walsenburg, Colo. Shipments of carnotite ore are being made from Dove Creek, Colo., to Monticello, Utah. F. A. Sitton, the "uranium king" of Colorado, has several operating mines in this area.

In a bulletin issued in December of this year, the Commission recognized five major classes of uranium deposits; stating that, although uranium is thought to compose .0004 per cent of the earth's crust, it occurs sparingly in concentrations, the chief known forms of which are:

(1) high-grade pitchblende deposits assaying more than 1 per cent $U_3O_8$. Best known of this kind of deposit are Eldorado mine on Great Bear Lake, Northwest Territories; Shinkolobwe, Belgian Congo; and Joachimstahl in the Erzgebirge, Czechoslovakia. The first two occurrences have supplied most of the material used in this country.

(2) the carnotite-type vanadium-uranium ores which occur in flat-lying sandstone beds in the Colorado Plateau area. The Commission stipulates that such ore must contain a minimum of 0.10 per cent $U_3O_8$ before it is acceptable at ore purchase depots.

(3) the vast gold district of the Witwatersrand, whose ores contain minor amounts of uranium.

(4) certain oil shales and marine sedimentary rocks containing minute amounts of included uranium. Conceivably, these may provide a considerable source of supply.

(5) miscellaneous deposits embracing pitchblende-bearing pegmatites, and placers which contain either uranium or monazite-bearing thorium.

In this country, the main deposits now being actively explored by the Commission are those of class two. Interest is concentrated in a great loop of Morrison formation which runs from central Utah east and south through the western part of Colorado and on down into New Mexico. Typical centers of activity are at Polar Mesa, Utah, near Gateway, Colo., and Calamity Mesa, Colo. Another promising development is underway in the White Canyon area, San Juan County, Utah, where potentially important occurrences extend south into Arizona.

A great deal of publicity has attended the discovery of a pitchblende vein in the old Cariboo Hill mine near Boulder, Colo. Admittedly, this is one of the most interesting discoveries of uraninite ore announced so far in the confines of the United States.

In Canada, uranium finds have sprung up all over the Dominion from the Northwest Territories down through Manitoba, Saskatchewan, and on across into Ontario, following that great arc of ancient rocks known as the Canadian Shield. A recent find is also announced in the Bridge River district, British Columbia. The latest sensation is a discovery by Robert Campbell in the Alona Bay area about 75 miles northwest of Sault Ste. Marie. Subsequent finds by an exploration subsidiary of the Jones & Laughlin Steel Co. add interest to the area where pitchblende occurs in veinlets, seams, and blobs in sheered granite near basic dikes.

As Gustafson so pointedly remarked recently in San Francisco, man has only just begun to explore in a concentrated manner for uranium supplies. Thus, the number of discoveries already unearthed is impressive. AEC chairman Lilienthal assures us that we are not faced with any acute shortage of raw material for the atomic energy program. However, the responsibility rests heavily on the mining fraternity to prospect seriously for the higher-grade type reserves of uranium ore. It goes without saying that this is warranted from a standpoint of the national welfare, but, thereafter, is the lure of profit; a motive sufficiently potent to keep adequate the supplies of most other metals in this country. Herein the government offers industry a proposition which in some respects is more attractive than that for gold.

The Atomic Energy Commission, with the U. S. Geological Survey, is publishing, and the Canadian Government has already put out, a booklet dealing with matters pertaining to the search, prospecting for, and the development of uranium ores. Further advice in this direction, too, can be had from the Atomic Energy Commission, Washington 25, D. C., or P. O. Box 30, Ansonia Station, New York 23, or Box 270, Grand Junction, Colo; also State Geological Surveys are prepared to give general counsel on questions pertaining to uranium occurrences.

A review of geological events of importance in 1948 would be incomplete without reference to the passing of a great spirit—William Harvey Emmons. Few of even the great geologists of our time have gone leaving behind such a sense of irreparable loss as was occasioned by his death.

Mining geologists can take comfort from the large-scale replenishments of our metalliferous ore supplies, which have been accomplished largely under their direction since the close of World War II. The greatest ore search in history is underway and results are encouraging though costly. Developments are on the whole orderly, with few spectacular new finds.

Uranium-ore developments occupy the center of the stage, and here too we seem protected by vast prospecting plans in hand by the AEC. Geological thought seems fairly united that we shall meet our future ore needs by using more efficiently and adroitly geological knowledge already available. The whole problem will be much advanced if our oncoming students can be trained to think more originally and to use more of that priceless quality—imagination.

My thanks are gratefully tendered to the geologists and engineers who took time to contribute to the review.

**Trackless haulage** increases underground with loaders and shuttle cars like this one at St. Joe.

# Metal Mining . . .

## . . . readjusting to meet high labor and material costs with increased mechanization and more technological improvements

BY E. D. GARDNER • SECRETARY, MINING METHODS COMMITTEE, AIME

In 1948 the metal-mining industry passed through another year of readjustments; catching up on development work again caused production to suffer. Skilled labor remained short in most districts. More mining companies are doing research to improve old practices or to evolve new ones to cut costs. The industry made real progress during the year in increasing the tons per man-shift of the production workers. Improvements in technology, however, have not kept pace with rising labor and material costs. The trend continued toward increased mechanization, the use of larger units of equipment, and the development of procedures for expeditiously handling coarse material. Considerable experimental work was done to improve drilling and blasting procedures.

In the early thirties, plans had been drawn up at a number of opencut mines for changing over to underground methods, as what was then considered the economic limit of stripping had been reached. Improvements in equipment and in procedures for drilling, loading, and transportation in surface work were rapid during the thirties, and few mines made the contemplated change-over to underground methods. This evolution in surface mining has continued; three underground copper mines in the Southwest were converted in whole or in part to opencut mines during the year 1948.

During the forties, the development of labor-saving equipment and devices in underground mines was accelerated. Improvements in rock drills and bits, mechanical loaders, haulage equipment, and ventilation practices were made in 1948.

### opencut mining

During 1948, Butler Bros. introduced on the Mesabi range a 25-cu yd Bucyrus-Erie dragline shovel for stripping operations. The bucket dumps into a hopper arrangement, which contains a grizzly for separating the boulders from the fine material; the undersize is fed onto a belt which

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conveys it about 1½ miles distant. Operation of this machine has been so successful that it has been concluded that it will improve the economies of stripping operations on the Mesabi range.

A completely self-contained mobile unit for secondary drilling in opencut mines will appear soon. It comprises a Diesel engine, a 320-cu ft compressor, four plugger drills connected to the compressor through four reels, each carrying 100 ft of hose, and a light drifter mounted on a boom. The pluggers will drill boulders ahead of a shovel, and the drifter will be used for drilling horizontal holes in large boulders set aside behind the shovel.

Millisecond-delay detonators are coming into more general use for improved fragmentation. Hole spacing and burdens can be increased with no increase of secondary breaking. The use of Diesel-electric locomotives about the pits has gained in popularity.

A rotary drill using a Hughes bit has been developed for drilling blastholes in soft formation and nonsiliceous limestone quarries. Under favorable conditions, drilling speed in a 6¼-in. hole is three times that of a churn drill, and drilling costs are lower. A relation exists between the pressure that can be exerted and the hardness of the rock that can be penetrated. A new drill that will exert seventy per cent more bit pressure is being developed for drilling larger-diameter holes and harder rock. A new rubber-wheeled wagon-drill frame weighing 110 lb has been used at the Pend Oreille mine for the past three years for bench work.

**Labor cost reduced** by one third using this rig to load holes at a 27 by 60-ft. face at the Bureau of Mines oil-shale mine.

## underground mining methods

A new mining method called "contour mining" now is in use at the Pend Oreille mine at Metaline, Wash., in an ore body with a 17 degree dip. This method reduces the footage of development drifts and raises in waste and will eliminate vertical shafts and eighty per cent of the surface exploration and exploratory drilling.

The Pend Oreille Mines and Metals Co. has now sunk 1800 ft of a 2600-ft incline with an inclination of 10 to 17 degrees. The incline will be equipped with a 30-in. belt conveyor which will transport all ore and waste at the rate of 350 tons per hour from the various mine levels to a new mill or to the dump. Men and supplies will be transported in the raise on rubber-tired, carry-all carts. The carts will be hauled by electrified tractor locomotives with power to be delivered by a Ben-Bow Tractroly system. The carts will be equipped to carry loaded mine-supply cars, which can be switched onto level tracks and thus save in handling costs.

At the Reeves MacDonald mines, Salmo, B. C., a new method has been devised for mining an ore body with a 54 degree dip. The manner of stoping is indicated by its name: "Removable Horizontal Pillar and Horizontal Open-Stope Method with Slushers."

Block caving is to be applied to a disseminated ore body at the Bunker Hill & Sullivan; progress is being made in preparing ore bodies for mining by this method at Butte. Shafts are being sunk for the development of the San Manuel ore body of the Magma Copper Co., which also will be mined by block-caving.

The highly selective but relatively expensive method of square-setting is generally used in the Coeur d'Alene district. During the last year or so, at several properties in areas where conditions permit, less selective mining, shrinkage, shrinkage-fill, and top slicing have replaced square-setting.

Mass concreting for support of heavy ground is increasing in use. Keyed concrete and wooden blocks are beginning to be used to form arched linings for continuous support. More care is being taken in the design and placing of timber sets; both steel and aluminum sets are finding greater application in metal mines. The use of a jumbo to place sets has cut timbering cost at some mines.

### carbide versus diamond bits

The field of the diamond drill is increasing in the construction industry, for surface excavations, for tunnel widening, and for drilling holes for grouting. The use of carbide bits has contributed a saving in collaring holes and drilling in overburden. In Canada, costs of drilling in overburden have been decreased during the past three years through the use of drilling mud. At the St. Joseph lead mine, diamond drills were mounted on army half-tracks and conventional trucks to supplement the standard trailer trucks.

Hudson Bay Mining and Smelting Co. at Flin Flon uses diamond drilling to break raises between levels as a regular practice. This procedure is also used to a limited extent at other places. A diamond-drill hole 230 ft long served as a pilot while raising and also for ventilation in the raise at one mine. The time saved in excavating the raise more than paid for the cost of the drill hole.

The practice of drilling blastholes with diamond drills has decreased because of the high cost of diamonds. At some places, such as the underground limestone mine at Bellefonte, Pa., where diamond consumption makes up but a small part of the total mining cost, probably no particular hardship is felt. On the other hand, at the Holden, Wash., mine of the Howe Sound Co., where diamond consumption is relatively high, the use of diamond-drill blastholes has been virtually discontinued.

When diamond-drilling costs began to increase at an alarming rate, it became apparent that improvements in the drilling practice at the Holden mine would have to be made. Accordingly, experiments with percussion drills using carbide bits and sectionalized drill rods for drilling long blastholes was begun early in 1948. As a result of the tests, diamond drills are now being completely replaced with percussion drills for ore breaking except in special cases where holes over 70 ft in length are required.

As AX holes 1 15/16 in. in diameter were drilled as standard practice, it was desirable to approximate this size hole with percussion drills; 2-in. tungsten-carbide bits were tried successfully with 3-in. drills. Next, 4-in. percussion drills with 1⅛-in. round drill rods and type-2 couplings were adopted. Holes up to 64 ft were then drilled successfully. As a result of this experimental work, a decision was made to convert all blasthole drilling from diamond drills to percussion drills, except in special cases.

Original research work in regular drift rounds with 1½-in. tungsten-carbide bits indicated that the bits would not stand up with drills with larger than 2⅝-in. piston diameter. Work with long holes showed that larger drills could be used because of the cushioning effect created by the additional weight of the drill rods. Drills of 3-in. piston diameter were then used successfully with ⅞-in. sectionalized and type-H couplings. The down holes, however, were difficult to control and further changes were necessary.

Some interesting comparisons between diamond drilling and percussion drilling now can be made. Diamond drills average about 22 ft per bit and about 28 ft per drill-shift. Two-inch tungsten-carbide bits with 3½-in. machines averaged about 56 ft per bit and 70 ft per drill-shift in September and October. During this period, three machines with experienced drillers were employed, and length of holes was limited to 35 ft. In November and the first half of December when two 4-in. machines and two 3½-in. machines were in use, the average footage approached 100 ft per bit and 54 ft per machine-shift. During this period the two 4-in. machines on trial averaged 72½ ft per machine-shift and the 3½-in. machines 37 ft per machine-shift. Maximum length of holes drilled was 65 ft. The decreased footage of 3½-in. machines in the November-December period is due to the increased length of hole drilled and inexperienced drillers who were being trained in this work.

The change-over from 3½-in. to 4-in. machines has now been completed, and six of the larger machines are now operating with 2-in. tungsten-carbide bits and 1⅛-in. round sectionalized steel. Further experimental work is planned in the near future with 1¼-in. round steel and 2⅛-in., or possibly 2¼-in., tungsten-carbide bits.

The field of tungsten-carbide rock bits was increased during the year, with several companies pushing sales. Considerable research work was done to improve the bits, but more remains to be done to make them economical at many mines. Their relatively high cost generally makes steel bits more economical in soft and medium ground where conventional drilling practices are followed. Carbide bits, however, are a necessity in some ground where holes are drilled with long changes of drill rods. A total of 63,559 ft of hole was drilled to mid-December with tungsten-carbide bits at the St. Joseph mines, with promising results.

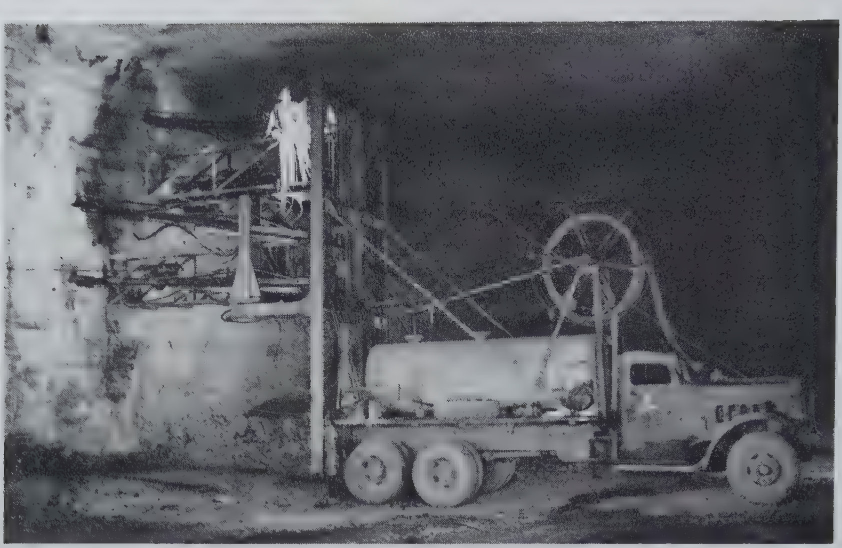
One test at the Bureau of Mines oil-shale mine indicated that drill-rod breakage was substantially reduced for drilling holes with a 10-ft drill rod by substituting a bit with a tungsten-carbide insert for one hard surfaced with tungsten carbide. The cutting edge of the insert bit remained sharp longer than the one with the hard-surfacing; it was thought that less shock that caused fatigue failure was occasioned by using the insert bit.

### drilling practice

Experimental work was carried on throughout 1948 at the St. Joseph mines to determine optimum size of drill hole and optimum amount of burden on each hole and best average angle of holes with the rock face in stopes to produce the most economical breaking results. Tests were also made to determine the relationship between the size of the holes and the powder factor per ton of ore broken as well as to determine the percentage of the length of powder column to the total length of the hole.

The Bureau of Mines at Rifle, Colo., has designed a movable compressor comprising two 750-cu-ft compressors with motors, an air receiver and a water tank. The motors will use the same current as a 3-yd electric shovel employed for loading oil shale, and the same electrical outlets will be utilized. An appreciable saving is anticipated; there will be no loss of drilling efficiency because of line losses, and the only air and water lines needed will be hoses connecting the air receiver to a drilling jumbo.

As a result of extensive research during the past two years, the International Nickel Co. has developed a



**Four drills,** two men, and a jumbo save time drilling with 15-ft drill rods and hard-surfaced bits at Bureau of Mines oil-shale mine.

round in which the burn holes break to a center hole reamed to 2¾ in. The first burn hole is drilled 2 in., the second 4 in., the third 6 in., and the fourth 8 in. from the center hole. Rounds in hard ground up to 12 ft deep are pulled readily by this method, with a relatively low consumption of powder.

The breakage of drill steel is an important item of expense at mines where long rods are used for drilling. Improved results are reported by the use of alloy drill rods, but there still is plenty of room for further improvement. Alloy-steel rods have been used extensively in Canada; their use has resulted in a substantial reduction in breakage of rods. Moreover, noticeably higher drilling speeds are obtained with ⅞-in., quarter-octagon rods in long lengths than with carbon steel of the same size and length. Apparently greater rigidity of the alloy steel contributed to this result.

Further developments were made on mechanically-operated jibs and multiple-drill carriages for mounting two or more drills for use with long power feeds. Jumbos are now standard equipment in the Tri-State field and are being improved from time to time. Long feeds on jumbos were first used in this field; the length was limited to the life of the bit in use. An efficient drill carriage for drilling 25 by 60-ft headings was developed at the Bureau of Mines oil-shale mine. It mounts four drills, which are operated by two men. Fifteen-foot drill rods with hard-surfaced bits are used for drilling the holes. At a Canadian mine one miner operates two drills on a hydraulic jib in an 8 by 10-ft heading and drills a round in a shift. The holes are started with a 6-ft rod and finished with a 12-ft rod. The operations are staggered permitting continuous operation of the drills.

The elimination of lost drilling time while steel changes are being made permits more footage to be drilled per drill-shift and reduces the manual labor. The mechanically operated jibs and long feed slides reduce the labor of changing positions of the drills. The saving in labor is considerable. Bits that will drill at least the full length of a change, of course, have to be employed.

Experiments in the use of a cheap detachable bit that can be discarded after drilling one hole promises to reduce drilling costs in the Tri-State field. The "throw-away" bit with alloy-steel rods shows satisfactory performance as to drilling speeds, costs, and convenience in the Coeur d'Alene.

E. D. Gardner

A piece of equipment for charging drill holes in a 27 by 60-ft heading has been designed and put in use at the Bureau of Mines experimental oil-shale mine. The labor cost of charging a round was reduced by one-third. The unit is a 5 by 10-ft working platform mounted on a Wagnermobile fork-lift truck.

## haulage

In some of the mines of the Tri-State district, slusher hoists mounted on mobile ramps are being replaced by Diesel-powered shovels of the Eimco and Allis-Chalmers types.

There is a general increase in trackless haulage underground where conditions are favorable. Shuttle cars being used in connection with Joy loaders have been introduced in some metal mines. Twelve HR Joy loaders and sixty E shuttle cars were installed in the St. Joseph mines, with favorable results. Eighteen shuttle cars previously were in use in an iron mine in Tennessee; about 175 are in use in nonmetallic mines, other than coal.

Conveyor belts to replace more expensive conventional car haulage have been introduced, particularly in underground iron mines. A belt conveyor has been installed in the Athens mine of the Cleveland Cliffs Co. at Ishpeming, Mich.; it may open up interesting possibilities in metal mines. The belt is installed in a transfer drift handling ore from ore passes to the main haulage drift. An innovation consists of the addition of a mobile chain feeder mounted on rails over the belt proper, permitting the feeder to be located under any of the ore passes. The feeder takes the impact of the material coming from the ore chute, and gets it in motion in the direction of belt travel before feeding it on the belt. This installation replaces a slusher hoist. It is believed that some original difficulties have been overcome.

Diesel truck haulage is now generally accepted as the cheapest and best practice to handle large tonnages in underground mines where the ventilation is adequate. Considerable interest was shown regarding the use of Diesel locomotives in coal, metal, and nonmetallic fields during the year. A second 5-ton Diesel locomotive was installed at an underground limestone mine in Wyoming. This locomotive is equipped with air brakes and a new type of exhaust gas conditioner. The performance of this unit is regarded as satisfactory. A new Diesel installation has been made in the Treasury tunnel of the Idarado Mine Co., Ouray, Colo., replacing the older unit now in service on the surface.

One of the outstanding experimental developments during the year is application of Diesel electric power to shuttle cars in a nonmetallic mine in Texas. These installations are experimental but are watched with considerable interest.

Laboratory experiments have been made on removing aldehydes from the exhaust gases of Diesel engines by using chemicals. The results of these tests are reported as satisfactory. Field tests of this method will be conducted in the Bureau of Mines oil-shale demonstration mine at Rifle, Colo., early in 1949. Increasing use of Diesel power underground, both in haulage and in portable units, such as compressors, tractors, and other equipment, can be expected when Diesel engines are manufactured that will pass the permissibility tests of the Bureau of Mines.

Hoisting on belt-conveyor systems is coming in where conditions are favorable. A 25,000-ft inclined conveyor was installed at the Sullivan mine to raise ore through a vertical distance of 680 ft. The conveyor requires only 480 hp as compared to 1800 hp for a hoist.

Scraper hoists were used in sinking the Metaline incline; the average advance for the first 1050 ft was 1.3 ft per man-shift. A self-loading skip has been introduced at the Bunker Hill & Sullivan to expedite sinking incline shafts.

Use of bottom-dump skips and of rubber-tired skips has increased. An improved wedge-type safety dog for cages has been introduced. There was a more general use of radio-telephone and radio-bell system for hoisting communications.

There was an increased use of corrosion-resistant material in pumps and water lines to combat corrosive mine water. Electronic-controlled pumping has been introduced. More attention is being given to sealing off water by grouting procedures.

The new cooling system at the Magma Copper mine was put in operation in August 1948. The underground installation comprises six units—two each on the 4200, 4400, and 4600-ft levels. The units on the 4200-ft level and one on the 4400-ft level have been completed. The temperature of the air, at the position of the second unit on the 4200-ft level, was lowered from a wet bulb of 94F and a dry bulb of 111F to a wet bulb of 67F and a dry bulb of 72F one day after the first unit was started.

Lightweight alloys are used to a greater extent to reduce weight and thus cut power costs. Automatic and remote controls are going into use to increase speed and efficiency of operations. An innovation quite generally used in the Coeur d'Alene is a locomotive operated by low-pressure compressed air. It is found useful and handy, particularly for filling stopes and for handling materials. A telescoping mast carrying a drill mounted on a 10-ft sash is now being tried in the Tri-State field in an endeavor to lower the cost of taking down rock in the roof.

This article was prepared with the aid of members of the Mining Methods Committee and with the help of other members of the Institute, by correspondence. The assistance of the following is especially acknowledged: E. R. Borcherdt, W. P. Goss, O. J. Neslage, John J. Curzon, Francis Cameron, S. S. Clarke, J. Murray Riddell, C. A. R. Lambly, J. B. Haffner, R. D. Longyear, H. A. Walker, J. H. East, Jr., W. C. Lawson, and F. S. McNicholas.

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## Papers Wanted for First Pan American Engineering Congress at Rio Next July

The South American Union of Engineering Associations will hold, in co-operation with engineering societies throughout the Americas, the First Pan American Engineering Congress, in Rio de Janeiro, July 15-24, 1949. The meeting will be preceded by a meeting of engineers in Sao Paulo from July 9 to 13. The agenda has been made broad, and includes the main topics of transportation and communications, construction, power, urban and rural engineering, sanitary, industrial, and mining engineering and geology, and teaching engineering.

Papers on metallurgy are desired, including steel production and its development in the Americas, steel and pig iron, iron bars and high-grade steel, sintering, powder metallurgy, and the metallurgy of nonferrous metals and alloys. Mining engineering papers will include discussions of mineral reserves and production, mining methods, scientific prospecting, mining legislation and its effect on development by foreign capital, governmental and private interests in mining, and financial incentives for mining development in each country, standardization of products, studies of deposits of specific ores, and brief résumés of mining in each country. Several topics in the field of geology are suggested, including mapping, paleogeography, common geological problems, co-operation in publishing geological knowledge, aerial photography as an aid in geological reconnaisance, and a brief summary of the geology in each country. Papers on both solid and liquid fuels are also desired.

The Engineers Joint Council is sponsoring the Congress and inviting the participation of United States engineers in the program. The papers need not be specially written for this meeting if they are of interest to the international group. They should be limited to 4000 words, with a 250-word abstract, and must be submitted in Brazil by April 30 so should be in the hands of the Committee on International Relations, Engineers Joint Council, 29 W. 39th St., New York 18, N. Y. by April 1. Prospective authors are urged to correspond with this committee as soon as possible. Also, those who plan to go to the meeting should address the Committee for further information.

**Humphreys spirals** making a heavy-mineral concentrate out of the sand fraction of the tailing prior to treatment by flotation, tabling, and magnetic separators in the new tungsten section at Climax.

# Minerals Beneficiation . . .

## . . . *shows trend toward rod mills, redesign of flotation cells, heavy-media separation, and fluidization*

By J. F. MYERS, E. H. CRABTREE, AND S. R. ZIMMERLY • CHAIRMAN AND COMMITTEMEN, MINERALS BENEFICIATION DIVISION, AIME

Minerals beneficiation progress, for 1948, shows no phenomenal development. Nevertheless, the boys have been consistently putting one foot down ahead of the other, and, consequently, are getting along the road to wherever they are going.

Professor Taggart made an offhand statement, that after the time of the conception of an idea, an average of eleven years is required to ding-dong it into successful operation—or words to that effect. Contemplating the activities over the past years, one must agree with that remark. This constitutes a challenge to the beneficiating technicians that they are accepting, if one can gauge the trend of 1948. It is sad to relate that this impetus comes not from Simon-pure love of technical achievement but from the old club of dollars and cents. With the price of base metals what it is, and the cost of labor and material on the up side, there is work to be done.

Research is evident on all sides, but again the steel companies seem to be out in front for all-out activities on research. Perhaps that is as it should be, as they were caught a bit off base.

Jones and Laughlin came in with a beautiful laboratory this year under the direction of F. X. Tartaron. Cleveland-Cliffs has about completed its new laboratory. These, added to the efforts of Oliver, Hanna, Butler Brothers, Pickands Mather, TCI, and others, should surely knock a bit of fruit off the tree of knowledge.

If one can judge from visitors from all over the world, research is of prime importance everywhere. We can be grateful for the constructive contributions of these friends from abroad.

Along this line is the commendable effort of AIME's Research Committee under E. R. Kaiser. A subcommittee on comminution was formed in 1948 under Fred Bond. A subcommittee is contemplated on gravity concentration for 1949.

Laboratory procedure on flotation is still in a deplorable condition, as batch test work usually does not follow in operation. One Canadian plant, treating a massive sulphide, operates a 7 by 12 ft mill, as required, in closed circuit with a classifier for the sole purpose of providing ground pulp for laboratory flotation tests.

The theory of flotation got a nice impetus with papers by Melvin Cook and others of Utah University. The layman dreams of seeing the world's eminent theorists put on an outlying island with nothing but a G string and a few fish hooks until they get together on their ideas. It might be helpful!

Instrumentation and autocontrol came to the front in a big way during the year. IMC's Norylan phosphate plant, designed by I. M. LeBaron, is the plant of the year, from the control and instrumentation viewpoint.

Marquard, of Combined Metals, is also doing outstanding work on controls. Others are beginning to realize that operating troubles are simply unsolved control problems. Yet critics of instrumentation and autocontrol remain in the majority. Well, it's like this: A round slick jug is hard to manipulate. Some good liquid is lost as it trickles down your chin, over your vest; some gets in your nose and even into your ears upon frequent application. Put a handle on the jug, and it can be gracefully thrown over the upraised arm, and steadied in the crook of the elbow. The ensuing controlled flow of liquid sets up a rhythmic gurgle that meets the approved traditions.

## material handling

There seems to be nothing that equipment manufacturers cannot do, if given the opportunity. Everything gets bigger and better. Typical is a 42-in. single-belt conveyor, 2449-ft centers with a vertical lift of 729 ft in an Alabama coal mine. As for pumps, they lift vertically up, vertically down, and horizontally in big or little quantities. Automatic control and high efficiency is fast making centrifugal pumps a big factor in one-level plant design. Extensive laboratory tests indicate advantages in using underwater screens for fine-mesh sizing. Better capacities, longer screen life, and less blinding are indicated. Highest praise goes to the equipment manufacturers for their co-operative attitude with the milling industry.

## coarse and fine crushing

Development of the hydraulic accumulator will, in all probability, ring the death knell on all types of springs in crushers. All crusher manufacturers are giving thought to the matter. Allis-Chalmers is coming out with a complete new line of hydraulically-supported gyratory crushers. Another well-known crusher firm is flirting with hydraulic accumulators, instead of a mass of springs.

St. Joseph Lead Co.'s new crusher plant at Balmat, N. Y., went into operation early in the year. Designed by J. J. Burns, all crushers are of the gearless type and are manufactured by Kennedy Van Straun. In crushing 10 in. ore to minus ¼ in. in two stages, a nice healthy reduction in power and cost is reported. The New Holland crusher will get a tryout in the mining field. W. L. Ziegler, of Pend Oreille, and S. S. Rogers, of Anaconda, have trial plants under way.

## rod mills

At long last there is a possibility that beneficiators may find out something about this machine. When one stops to consider the years of effort that have been given to developing ball mills, rolls, etc., it would be reasonable to assume that an equal amount of effort will bring the rod mill to a high degree of efficiency. It is appealing more and more to operators for fine crushing preceding the ball mills.

Consolidated's big 12 by 11½-ft rod mill went into operation in December. Designed by Hardinge and built by John Inglis, the mill has a 1000-hp motor and will use 3 and 3½-in. rods. East Sullivan, Quemont, and Snow Lake are other new Canadian plants to use rod mills in the flowsheet. Anaconda's one rod mill has been so successful that the outfit is going all the way with eight more in the copper concentrator and two in the zinc plant. Chuquicamata will use the rod mill-ball mill combination in its huge Chile concentrator.

How coarse a feed these machines can handle is demonstrated by Bradley, Anaconda, and Benson Mines, where the feed shows as much as 25 to 35 per cent on a 1½-in. screen at times. How much tonnage they will handle is still a guess. Hayden has demonstrated that its 9 by 12-ft mills can do 4800 tons, day in and day out. Tennessee's 6 by 12-ft rod mill is loafing along at 2200 tons per day. On a scalping crush, Maxson reports 350 tons per hour through a 9 by 12-ft mill at Trout Lake.

There is considerable difference of opinion as to rod-mill liners, but I am of the opinion that the developments at Anaconda and Bradley will be interesting to watch; as will be Consolidated's liners designed by H. R. Banks. All three possess features beyond simple lifting bars.

As tonnage per rod mill increases, it is becoming apparent that a good chute feeder is desirable. This is especially true since eliminating closed circuits at the crushers ahead of the rod mill is one of the rod mill's main economical features.

## ball mills

This expensive step in beneficiation received a lot of attention during the year. Hardinge and Ferguson present evidence to support the fact that high initial cost is warranted for large slow-speed mills. Jack White, of Mufulira, presented a paper showing competitive results of a well-known low-discharge grate mill versus a well-known high-overflow mill. Since both mills operated with a 7200-lb ball load, he presents a real comparison of results.

With the high cost of balls and liners, the trend is definitely to high- or trunnion-overflow mills for economical reasons. Chuquicamata will use trunnion-overflow mills instead of grates. Kennecott's new mills at Hayden (11½ by 12 ft) will be trunnion overflow and slow speed. Tennessee's new 11 by 9-ft ball mill has a 12-in. discharge opening and is slow speed. Climax reports higher efficiency for trunnion-overflow mills. Nevertheless, the grate type permits any given mill to accomplish more work but, apparently, at a price.

The matter of horizontal ball migration, referred to in the past Annual Reviews, can now be pegged as a loss of six per cent in efficiency as reported by Garms at Hayden.

There is little doubt but that coarser feed can be ground in larger diameter mills with smaller balls than can be used in small diameter mills.

The shortage and high prices of

balls in Canada caused Crocker, of Lake Shore, to experiment with pebbles, from Lake Shore ore. He finds that on pebble mills the difference in capacity and horsepower between high discharge and low discharge, with grates, is 40 per cent. This is more than double the difference when comparing steel charges. The difference comes, of course, in the greater percentage difference between pulp gravity and pebble load, and pulp gravity and steel load. Using the existing mill ends, we will expand the shells of the present 5 by 16-ft mills to 6 ft 8 in. by 16 ft which, with grates, will pull the same horsepower as the 5 by 16 ft-mill with steel balls.

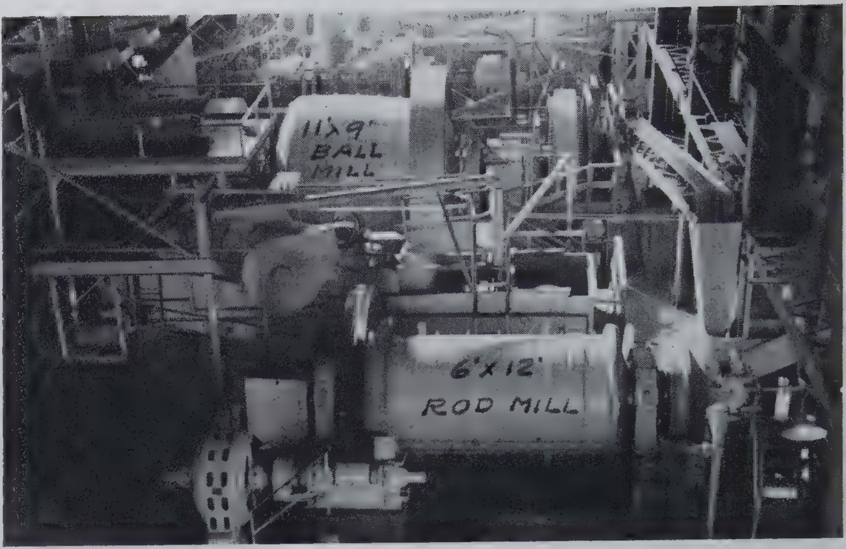
Weston at Aerofall Mills Ltd. is carrying on extensive experimental work with tungsten-carbide balls. Although there are no reliable data as yet relative to wear of the tungsten-carbide balls, the indicated life versus steel balls appears to be between 84 and 100 to 1; the relative cost is between 50 and 60 to 1. At the present time, the high cost of tungsten carbide makes it applicable in special cases only rather than for general use.

A great difference in opinion exists as to which type of ball-mill liners is best. One of the projects of the Minerals Beneficiation Division for 1949 will be to prepare a symposium on this subject for the February meeting in 1950. This will be under the direction of R. H. Ramsey. Ball rationing continues to be effective and plants are finding this way of operating economical.

## concentration processes

The reader gets a break at this point as this part of the Annual Review is presented by E. H. Crabtree, director of concentration, Eagle-Picher Mining and Smelting Co., and chairman of the MBD Unit Process Committee on Concentration.

During the year, most new developments in flotation practice of base-metal ores were confined to middling and cleaner circuits, and to changes in machine design. Flotation of the taconites is, of course, receiving a large amount of laboratory and pilot-plant work but results are not sufficiently mature for publication. At Noranda, interesting results are being obtained in floating relatively coarse gold from a deslimed tail; concentrates averaging 1.0 oz of gold per ton are obtained from a 0.03-oz feed, effecting a 30 per cent recovery and representing almost all of the contained free gold.



**Rod mill and Tricone ball mill** used by Tennessee Copper grind 2200 tons per day.

Consideration of the various factors in both pretreatment and flotation served to emphasize again the need for fundamental machine design. This was demonstrated in Canadian practice during 1948 by alteration to standard cells and, in some cases, replacements by entirely different cells took place. A Porcupine mill replaced impellors with Fagergren units; Noranda introduced air through hollow shafts in Denver cells.

Operators are beginning to recognize the fact that floating conditions in the head end of the flotation circuit are different from those at the tailing end. We can, therefore, expect flotation machines to cease being the same from end to end. McLachlan has long contended that shallow cells on the tailing end of the process make for a lower tailing. The new Quemont concentrator will use the shallow McIntosh cells as final tailing makers, as at Noranda. Manufacturers of the Denver cell now recognize this principle, and are providing adjustable weir overflows for low-pulp levels on the tailing end of their machines.

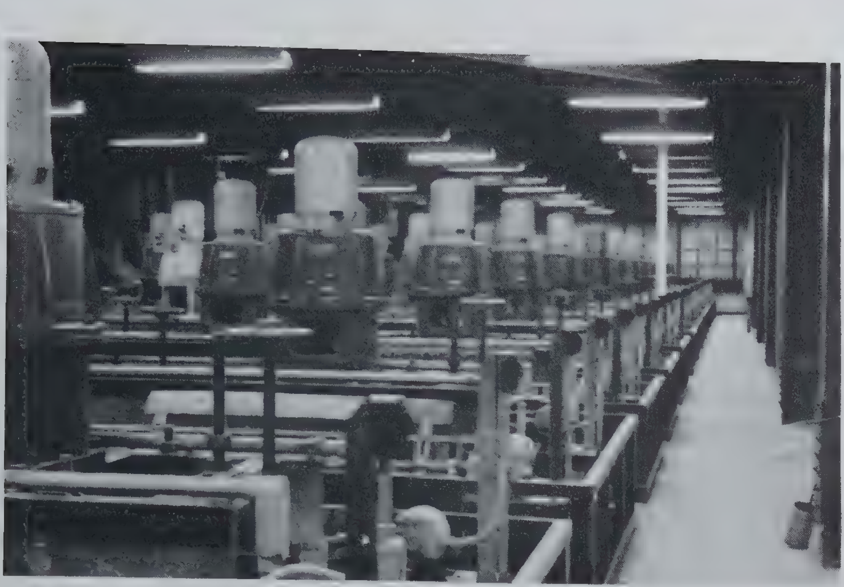
A few Booth flotation-machine plants appeared during the year. Operators are going to find these cells flexible, since it is relatively simple to change the relationship of the dual impellors to other flotation factors.

Ramsey suggested that four or five general types of machines should satisfy the varying requirements. One large company has now undertaken the study of the problem and hopes to be able to measure what might be termed the "floatability," not of a given ore, but of a given ore in a given machine, correlating this with standard tests in a standard laboratory unit. With such a method as a yardstick, flotation may finally evolve from an art into a science.

The studies of oxygen-sulphur compounds in flotation continue to be of great interest to the operators on heavy sulphide ores. An excellent treatise on these compounds will be forthcoming in an early issue of *Industrial and Engineering Chemistry*, by Olav Foss, of Stockholm University.

Leo Abell, of Cyprus, reports that proper aeration of pyrite with sulphur dioxide will reactivate the mineral, after complete depression with cyanide, etc. A somewhat similar scheme is currently used at Lake Shore.

In flotation, the outstanding new plant of the year was probably the Noralyn plant of International Minerals and Chemical. It uses International-turbo machines for roughing flotation, and Denvers for cleaning, and has a capacity of 1,500,000 tons of phosphate per year. Many new plants are being built all over the world and many more are being remodeled.



**International-turbo flotation machines** at the Noralyn phosphate plant are probably the outstanding installation of the year.

Tartaron, in one of his recently published papers, admirably described the problems and projected developments of the proposed iron-ore concentration plants. The enormity of some of the proposed plants is visualized when it is considered that from a 100,000-ton-per-day plant, some 30,000 to 40,000 tons of concentrates per day will have to be dewatered, sintered, and shipped. Most of us who are familiar with high-tonnage mills are also used to high ratios of concentration, for which concentrate handling and disposal are secondary problems.

The large number of heavy-media concentration plants installed during the year and projected for 1949 indicates that this process has become an integral part of beneficiation.

Metallic nickel, while expensive, makes an excellent medium if iron must be kept out of the concentrate, as is true with some industrial minerals.

The Mascot hms plant of American Zinc followed the example of Eagle Picher's Central mill and changed from a galena medium to ferrosilicon in early November. Patino plans to make a similar change next month. Doubtless, one of the principal virtues of the change is comparative cost—galena concentrates, at this time, being worth $292 per ton (Joplin—80% base) as against an 85-15 ferrosilicon pig price of $88 per ton fob manufacturer's plant.

New installations of equipment for gravity-concentration treatment of fine material include jigs, tables, Humphrey spirals, Driessen cyclones, and Denver-Buckman tilting concentrators. A new plant, built during the summer of 1948 by The M. A. Hanna Co. at Iron Mountain, Mo., for the treatment of iron-ore tailing at the rate of 1200 tons per day, uses three 42 by 42 in. specially-designed Pan-American 2-cell cross-flow jigs, treating minus ½ in. material. Concentrate is reground in an open circuit rod mill to 8 mesh and rejigged to produce a 58 per cent concentrate. The performance of these jigs indicates that within certain size ranges efficient work can be done on iron ores by hutch concentration which, at the present time, is a rather neglected art in the field of iron-ore beneficiation.

The trend of jigging in gold work on dredges, for cleaning a concentrate composed almost entirely of magnetite, is now definitely toward a fast, short stroke on mechanically operated units.

What will probably be the world's largest table plant will be completed in the near future in the Belgian Congo, using Deister concentrator equipment to treat a tin ore. The increase of mechanical mining in the coal industry has increased the percentage of refuse in raw coal which, together with the demand for cleaner coal, has required the efficient cleaning of the finer sizes. In twelve new coal-cleaning plants, either recently completed or under construction at present, the Chance process will be used in eight instances, heavy media in eight, and Baum jigs in two, for treatment of the coarse sizes; tables will be used in all 12 plants for treatment of ½-in. by O-size material.

Humphreys spirals are now operating in five ore-concentration plants, the largest installation being that of Cleveland-Cliffs at the Hill-Trumbull mine, where 84 spirals treat 100 tons per hr of jig-type ore. Climax, with 128 units, continues to recover tungsten concentrates from its molybdenum flotation tailing. International Minerals and Chemical has 154 spirals at Achan and 88 at Noralyn for the recovery of phosphate sands. Other new plants include that of Calco Chemical in Virginia on ilmenite, the Turkish Kavat mine on chromite, and that of the Hudson Coal Co. on anthracite silt. At present, the Starke, Fla., plant of the Humphreys Gold Corp. will start using more than 1000 spirals to treat 25,000 tons of sand daily for the recovery of titanium minerals and zircon. This plant is located on two barges floating in the pond made by a suction dredge.

The first commercial installation of the Dutch State Mines cyclone separator started at the Keystone, S. Dak., plant of the Lithium Corp. This plant consists of a Mobil-Mill heavy-media unit combined with a 6-in. cyclone. Magnetic separation equipment for media cleaning will handle both units. American Cyanamid has done a considerable amount of large-scale testing with the cyclone on various domestic and foreign ores. It is expected that several new cyclone-separator plants will be installed during 1949.

Following the development of the Denver-Buckman tilting concentrator at Sullivan several years ago, this gravity concentrator for the treatment of fine slimes, containing high-density material, has had considerable acceptance. Recent applications, in addition to tin treatment in Bolivia, France, Belgian Congo, Algeria, French Morocco, and the Soviet Union, have been on other heavy minerals such as wolframite, sheelite, chromite, and gold. A Swedish plant recovers scheelite from flotation tailings: in Australia they are being used on a chrome slime; and in Malaya the concentrator supplements a dredge operation.

In conformance to the labor-saving trend of all mills in general, the gold plants of South Africa are mechanizing the old blanket strake, utilizing cerrated rubber blankets in place of English corduroy. Three new dry concentrators which would seem to offer promise have been described by Long. These machines, developed by the Bureau of Mines, instead of utilizing differences in specific gravity, use differences in shape, magnetic susceptibility, or electrostatic conductivity. For separations such as vermiculite from gangue minerals, molybdenite from pyrite and chalcopyrite, and cleaning of graphite concentrates, the shape separator was successful. Other nonmetallic minerals were separated electrostatically, and the magnetic equipment was particularly effective in the finer-size ranges in the separation of magnetic and nonmagnetic material.

During the year, the exclusive manufacturing and sales rights of the Fagergren flotation machine were acquired by Western Machinery Co. from American Cyanamid. The rights to the Chapman process of charcoal-cyanidation were assigned to Eagle Picher.

## hydrometallurgy

The reader's luck still holds good and this part of the Annual Review is presented by a well-recognized authority, S. R. Zimmerly, director of the Bureau of Mines at Salt Lake City.

The Calera Mining Co. has been actively investigating the hydrometallurgical treatment of cobalt concentrates for the production of pure cobalt oxide and electrolytic cobalt. Development work at the mine on Blackbird Creek near Forney, Idaho, was accompanied by pilot-plant operations, producing high-grade cobalt concentrates for chemical processing.

The availability of cheap caustic soda, as a by-product of chlorine production in southern Nevada, has stimulated research in the field of caustic leaching of oxidized lead-zinc ores at Boulder City, Nev. The investigation by the Bureau of Mines has indicated that many of the objections to caustic leaching, followed by electrolysis, are not insuperable, and results have been sufficiently encouraging to justify the Basic Reduction Company's trying the process on pilot-plant scale at the former Basic Magnesium plant at Henderson, Nev.

The Arizona porphyry-copper operators continue to be the major producers of copper by the leaching or leach-flotation processes, and the problem of the recovery of copper from oxidized-porphyry ores remains dominant in the area. The Anaconda Copper Co. is also faced with the problem of treating mixed oxide-sulphide ores in conjunction with the plan for large-scale mining of the low-grade copper ores at Butte. It is understood that leaching and leach precipitation are being investigated on laboratory and pilot-plant scale, as probable solutions to this problem. Encouraging laboratory results have been obtained in both the United States and Mexico, employing leach precipitation processes for the treatment of the oxidized-copper ores from the Boleo district of Lower California. This district is second only to Cananea in production of copper in Mexico, and the treatment of the reserves which are too low grade for direct smelting presents an interesting problem.

G. D. Van Arsdale has pointed out that the present trend in copper mining is toward open-cut methods, such as are employed at Inspiration, Cananea, Bagdad, and elsewhere, and that the total amount of copper in the submarginal overburden, removed in stripping, is great. He feels that a cheap method of treatment, possibly heap leaching, may permit the economic recovery of copper now piled as waste.

A new plant employing heap roasting and water leaching has been placed in operation by the Toncrae Mining Co. to treat the little-known secondary copper ores of Carroll County, Va. C. H. Thompson described the operation in the July 1948 issue of the *Mining Congress Journal* and stated that the Company has plans to use sponge iron instead of scrap to precipitate copper from the leach solutions.

There is considerable interest here and abroad in the use of sponge iron as a precipitant of copper, especially when detinned scrap may not be readily available. An integrated process, in which sulphur dioxide from the roasting of pyrite would be used to render copper soluble and the residual iron-oxide sinter subsequently would be reduced to sponge iron for precipitating the copper, appeals as a natural economy.

Among references in the literature, *Chemical Abstracts* mentions a Canadian patent by Buchanan and Hendrickson, assigned to the Hudson Bay Mining and Smelting Co., on the purification of zinc electrolyte by passing it through a porous precipitating mass consisting of zinc or zinc dust. A Swedish patent by Bjorling, assigned to Boliden Gruveartiebolag, covers the continuous leaching of zinc calcine in three stages.

## cyanidation

In general, the trend in cyanidation of gold ores is toward improving known techniques and reducing costs. Probably the most interesting development in cyanidation in recent years is the treatment of claylike ores, with poor settling and filtering characteristics, by precipitating the gold and separating it from the pulp as a part of the leaching step, thus eliminating the troublesome and expensive thickening and washing. The best known application is the so-called carbon-cyanidation process, which makes use of the simultaneous dissolution of gold and its adsorption on activated carbon. A recent advance is the employment of coarse carbon submerged in the pulp in rotating wire mesh containers. This has now passed the experimental stage and probably will be incorporated into the flowsheet of a 1500-ton plant in the near future. The use of "Aerochar," developed by American Cyanamid, presents another variant of the process. The carbon is bonded with magnetite, and after it has adsorbed the gold it can be separated by a wet-magnetic separator.

The problem has been investigated from another angle in the laboratory of the Bureau of Mines at Salt Lake City. Here, the recently developed ion-exchange resins have been employed to precipitate the aurocyanide ion from the pulp. After virtually completely removing the gold from solution, the coarse resin is screened from the finely divided pulp, the gold is extracted from the resin, and the resin is recycled.

F. L. Bosqui, in a letter to the author, calls attention to several technical papers in the field of cyanidation that deserve special attention. In a paper in the *Transactions* of the Chemical, Metallurgical, and Mining Society of South Africa, entitled "Modern Metallurgical Practices on the Witwatersrand," A. Clemens discusses the trend of "all-sliming" and "continuous treatment" to replace the batch system on the Rand. He also states that stage filtration is preferred to countercurrent decantation, because of the relatively small volume of solution employed. Modern trends in Australia closely approximate those in the United States and Canada. A paper by Owen Mathews, "Fluo-Solids Roasting of Arsenopyrite Concentrates at Cochenour Willans Gold Mines, Ltd.," presented at the Winnipeg meeting of the Canadian Institute of Mining and Metallurgy, October 1948, describes the first installation of the Dorr Fluo-Solids reactor for roasting arsenopyrite concentrates prior to cyanidation.

In concluding the discussion of processes for the lixiviation of gold, the suggestion of a visiting metallurgist from England might bear some thought: "In consideration of the probability of chlorine being available at extremely low cost now, compared to the turn of the century, should not chlorination processes be re-evaluated?"

## equipment and processes

As a preliminary step to hydrometallurgical processes, the fluo-solids system is attracting widespread interest. This system, which permits the reaction of finely divided solids with gases at elevated temperatures under closely controlled conditions of temperature and gas composition and concentration in simple type reactors, presents almost unlimited possibilities.

The commercial application of the fluidization technique to metallurgical processes has been fostered by the Dorr Co. through its fluo-solids process. Commercial plants for roasting refractory gold ores, for lime calcination, and for carbon activation continued to give satisfactory operating results in 1948, and new plants are being installed in 1949. Research work carried on during the year gives indications that certain long-standing metallurgical problems may possibly be solved on a pilot-plant basis by the use of this process, in the not too distant future. Specifically, this includes the winning of copper and zinc from concentrates or ores by a sulphatizing roast and subsequent leach usually resulting in high recoveries; the recovery of metals such as tin, zinc, antimony, arsenic, and others by volatilization from a fluidized bed; the production of high-concentration sulphur dioxide through the controlled roasting of sulphide concentrates; magnetic roasting of low-grade iron ores for subsequent beneficiation; and many similar applications.

### South America

Our correspondent in South America summarizes the beneficiation situation as follows:

Shortage of foreign exchange and import restrictions have hampered normal activities in several ways; but on the other hand, labor troubles appear to have decreased as compared with last year. In many cases, the net results will probably show increased production, and better earnings for the year.

The Northern Peru Mining and Smelting Co. started development on a large copper property at Toquepala in southern Peru, and also on a lead-zinc property near Trujillo; at the latter, a 300-ton mill is planned. In northern Peru, work progressed on a new 150-ton concentrator for lead-antimony-silver ore near Huamachuco. At Huachocolpa, a new lead-zinc custom mill will be started; this is operated by the Banco Minero del Peru. The Cerro de Pasco Co. completed its 50-mile railroad and 10-mile aerial tramway to Yauricocha. This is expected to transport about 350 tons of 7 per cent copper ore to the smelter at Oroya.

In Bolivia, interest in heavy-media plants continues to increase; another of these was placed in operation at Potosi for treating old mine dumps. At Patino, the 5000-ton plant is to be converted for using ferrosilicon. At Colquiri, some trials were made with the Dutch State Mines cyclone.

During the year, the announcement was made that Chuquicamata would start the construction of a sulphide concentrator. The first unit is to be for 25,000 tons, and the eventual capacity considerably greater. The concentrator at Potrerillos is to be enlarged to a capacity of 25,000 tons per day. This involves two more ball mills, and the accompanying flotation units. Work was started on the new Government-sponsored custom smelter at Paipote; the smelter is expected to increase the production of copper from small producers in the northern district.

Gold has recently been selling in Chile for about $60 per oz on the free market. This has aided all the small-scale gold mines. Several of these are now using both flotation and cyanidation, even though the consumption of cyanide is unduly high. The old Andacollo district is said to be producing about 2400 oz per month.

Increased activity was reported among the tungsten producers. The drop in value of the Argentine Nacional should help many operators.

### Conclusion

Technicians and managers, who did not read, "Getting Your Money's Worth" by E. H. Rose, in the January issue of the AIME journals, should do so. Beneficiation matters are developing so fast that no one can hope to keep abreast of technical matters without informal visitations at the Regional and Annual Meetings. These meetings are developing into a clearing house for an exchange of ideas and experiences.

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## How Much Does Research Pay Off?

A method for determining the monetary return on research investments was described by Fred Olsen at a recent meeting of the Philadelphia Section of the American Chemical Society. Mr. Olsen, director of research and development of Olin Industries, Inc., described how his "Index of Return" is now being used by the Western Cartridge Co., a division of Olin Industries. Original work on the Index was begun in an effort to put a monetary evaluation on research projects conducted in Western's labs.

The Index, although still in an experimental stage, should prove useful to many concerns.

# Magnetite Mining and Milling . . .

## . . . *active in the East to meet heavy demand*

By J. R. LINNEY • CHAIRMAN, COMMITTEE ON MAGNETITE MINING AND MILLING METHODS, AIME

Demand for eastern magnetite in 1948 necessitated practically all eastern magnetite industries to operate on a six-day week, with the result that over 11,000,000 long tons of crude ore were mined, and the shipping products amounted to approximately 5,000,000 long tons. Reports indicate that operating on a six-day week and doing maintenance work on the seventh day was satisfactory and resulted in excellent continuity of operation.

In the Port Henry district, Republic Steel Corp. once again set new all-time records for the production of crude ore and total shipping product; 1,868,000 long tons of crude ore were mined, 945,000 from the Old Bed mine, 408,500 from the Harmony mine, and 514,500 from the Fisher Hill mine. Of the 969,000 long tons of shipping products, 663,800 long tons were sinter, 181,000 lump ore, and 115,200 concentrates.

The Cornwall operation of the Bethlehem Steel Co. produced 1,607,200 long tons of crude ore recovering 1,071,500 long tons of concentrates. The open-pit operations were on a five-day basis and the underground and concentrating operations were on a six-day basis. More than 50 per cent of the total production came from the underground operation.

The MacIntyre Development of the National Lead Co. at Tahawus, N. Y., operated without interruption in 1948 on a six-day week producing 3,500,000 long tons of material of which 1,500,000 tons went to the crusher and the remaining 2,000,000 tons to adjacent waste dumps. Of the 1,500,000 tons of ore delivered to the crusher, 300,000 tons were rejected by coarse cobbing and 1,200,000 tons were milled. In addition to the tonnage mined by the Company, a stripping contractor removed 600,000 tons of overburden. During the year, 250,000 long tons of ilmenite concentrate, 575,000 long tons of magnetite concentrate, and 490,000 long tons of sinter were produced. The flotation pilot plant which was installed in 1945 has been used as a production unit in addition to investigating metallurgical problems. It produced an average of 100 long tons of ilmenite concentrate per operating day all year. Additional housing units were completed and an addition made to the main shop garage to facilitate handling of larger truck units. The new YMCA building continued to give maximum community service through its bowling alleys, gymnasium, recreation and meeting rooms, and coffee shop.

The Clifton mine division of the Hanna Coal and Ore Corp. at DeGrasse, N. Y., made no changes in their mining or milling methods. Production of ore was stopped on Nov. 1, 1948, for mill repairs and to allow shaft sinking to a new level from which future production will be mined. With the sinking of the shaft in process, it is anticipated that 200,000 long tons of crude ore will be mined in 1949.

The Mt. Hope division at Wharton, N. J., operated by the Warren Foundry and Pipe Corp., hoisted and milled 222,189 long tons of crude ore yielding 56,021 tons of lump ore analyzing 60.50 per cent iron and 65,090 tons of fine concentrate analyzing 66 per cent iron. Operations were closed down from Oct. 19 to Nov. 22 by a strike. A shortage of mine labor still exists but mine development was speeded up to the limit of available mine personnel. Approximately 800 ft of a twenty-degree underground slope was driven below the 1700 level in the footwall rock of the Leonard vein. Drilling and mucking was done by a three-man crew using three Leyner machines, jumbo mounted, and a modified Eimco-Finlay air shovel. Excavation was started for the 2100-level crusher room, pump room, and sump. The 2100 level was advanced 850 ft to the ore contact south of the Mt. Hope fault and drifting will continue on this level during 1949.

Although the Alan Wood Steel Co. operating the Scrub Oak mine experienced a shortage of mine labor during the year, 482,200 long tons of ore were produced from which 165,200 long tons of concentrate were recovered. Development of the sixth level was started. The sinking of the shaft was completed in April and 3000 ft of main drift finished at the close of the year. The mine is now using about 90 per cent

**Concentrating mill and sintering plant** of Republic Steel Corp. at Port Henry, N. Y., which shipped 115,200 long tons of concentrates and 663,800 long tons of sinter last year.

carbide bits which have been successful. A Sullivan Hydro-Jib jumbo was used in one of the main headings. Drilling time was reduced by the use of the Hydro-Jib and the carbide bits, which considerably increased the speed of advance in the heading.

The Chateaugay mine at Lyon Mountain, N. Y., operated by Republic Steel Corp., hoisted and milled 1,273,575 long tons of crude ore yielding 386,100 long tons of concentrates. For the second consecutive year since 1946 Chateaugay operated on a six-day week basis without interruption. In the spring of 1948, stripping operations were started at what is known as the "81" open-pit and approximately 260,000 cu yd of overburden were removed during the year.

At the Richard mine operated by the Richard Ore Co., 215,831 long tons of crude ore were mined and the total shipping product amounted to 155,000 long tons. A new crusher was placed on the 1300 level and development was started for the new 1500 level.

Providing no unseen interruptions occur, the eastern magnetite industry should have a record year in 1949.

# Health and Safety . . .

## *. . . improved by reduced accident rates in 1948*

By **JOHN L. BOARDMAN** • CHAIRMAN, BUREAU OF SAFETY, ANACONDA COPPER MINING CO.; MEMBER, AIME

Accident rates for both coal and metal mines show a substantial reduction in 1948 below those for 1947. A great deal of work has been done and a good degree of progress attained in the 1948 accident prevention activities of the mining industry.

In the coal mines the decrease in the number of fatalities has been mainly due to the prevention and minimizing of major disasters. The reduction in the number of accidents in both coal and metal mines is less favorable than the reduction in accident rates per million man-hours of exposure because of the increase in employment.

Both, the coal mining section and the mining section of the National Safety Council have been active in the preparation and publication of safety posters, data sheets, and sound-slide films (lists of these may be secured by writing to the NSC). During the year, the technical mining magazines have been helpful in publishing various articles on accident prevention in mines.

An interesting bit of research by the Bureau of Mines indicates that Diesel-powered locomotives may be safer for underground use than electric trolley locomotives. A schedule of requirements that must be met by Diesel locomotives for safe use in coal mines was formulated in 1944, and in 1948 a schedule was also prepared for their use in mines where explosive gases are not encountered. Future work will be done to minimize the discharge of harmful gases in the exhaust.

### safety meetings

One of the principal safety efforts in 1948 was supervisor training for accident prevention and similar training for miners. These training programs are being conducted by several of the larger companies and by the Bureau of Mines for coal and metal miners.

Regular safety conferences are gaining in popularity. During the year conferences were held by the Lake Superior mining section and the Montana mining section of the NSC; the

Utah-Nevada Safety Society, and the conventions of the coal mining and the metal mining sections of the NSC in Chicago. There is no doubt that these conferences are a valuable aid in advancing safety in mining. However, in my opinion, they could be made much more effective if they were held in mining localities, as were the Lake Superior and Montana meetings. In this way attendance would be convenient for mine supervisors who are in the front line of the fight against mine accidents.

A suggested plan for increasing interest in the safety movement and providing better safety service for mine supervisors would be to have the National Safety Council hold an annual industrial safety conference in which plans for nation-wide activities would be made. In addition, an annual or even a monthly conference of mine supervisors in each mining district should be held. In these local safety conferences such organizations as the AIME, The American Mining Congress, the American Association of Mine Inspectors, and the various State mine operators' associations would be expected to co-operate. This would not only enhance the technical and educational value of the meetings but also, by concentrating the efforts of these organizations, would make it more popular and more effective in creating safety consciousness and increasing enthusiasm for accident prevention.

### first aid

During and since the war, first-aid training for miners has been neglected to some degree. It was through first-aid training that the Bureau of Mines rendered one of its greatest services to the industry. First-aid training is somewhat more valuable in mines than in other industries because of the difficulty in getting prompt medical or surgical service underground. But it has additional value in that it permits the miner, himself, to participate in the safety movement in a way in which he can take considerable pride.

Increased labor and material costs force an increase in mechanization. Mechanization, in turn, eliminates many accident hazards, but, at the same time, introduces new hazards which are gradually overcome as experience is gained. This makes accident prevention one of the more important duties of mine supervisors and it is through their constant effort that the industry's injury rate is being reduced.

# Mineral Industry Education . . .

## . . . has completed the first phase of reorganizing curricula and founding new schools and departments

By **CURTIS L. WILSON** • CHAIRMAN, MINERAL INDUSTRY EDUCATION DIVISION, AIME

Mineral industry education has now progressed through the initial steps of a distinct transition stage. Colleges and schools of mineral engineering met the challenge of the postwar years 1946 and 1947 more successfully than they realized at the time. Faculties had taken advantage of the period of low enrollment to plan for an increased demand for education. The year 1948 showed that these plans had been well laid. But the demand for education in the fields of the mineral industries once again exceeded the estimates. Last fall's enrollment in most departments surpassed that of a year ago. The number graduating next June will be the largest in history and the 1950 classes will be still larger. After that a decrease is expected. Total student enrollment in all branches of engineering will then remain below the 1946-1950 peak for a number of years. Unless unforeseen factors appear, enrollment will rise again at the end of the next decade to a new and more or less permanently high level.

The present transition has exhibited itself not only in new and revised curricula but even in schools and divisions. Stanford expressed satisfaction with its new School of Mineral Sciences. Reorganization at the University of Utah evolved its new College of Mines and Mineral Industries. A year or so ago the University of Washington changed the name of its College of Mines to School of Mineral Engineering. Such changes exemplify the efforts that are being made to redefine objectives and to correlate more effectively the various courses of study. While complete uniformity of methods and objectives in all colleges may never prove desirable, some degree of standardization of nomenclature would contribute to clarity of purpose.

The five-year plan continued successfully at Ohio State and Minnesota. Of the humanities electives, Minnesota students preferred psychology to the biological sciences. Two additional combinations in the five-year curricula were added at Texas A&M, one combining petroleum engineering and chemical engineering, and one petroleum engineering and business.

New curricula appeared in many schools. Petroleum refining engineering at Colorado School of Mines and petroleum engineering at Montana School of Mines became well established. Louisiana Polytechnic started a new department of petroleum engineering. Alabama added a petroleum and natural gas option to its mining curriculum. Geological engineering, as a separate curriculum, was introduced at the universities of Kansas, Nevada, and Utah. California changed its economic geology to a curriculum in mineral exploration.

Coal mining received more attention, as it well deserves, and enrollment increased as students became cognizant of the attractive opportunities in that industry. Last June the National Coal Association published a directory listing 33 mining schools which teach that subject. The mining department of the University of Pittsburgh decided to specialize in coal mining. Options in coal mining were introduced at the Colorado School of Mines and the University of Utah. Illinois used a coal advisory committee for both its undergraduate and graduate programs.

New courses offered at many institutions would seem to indicate a higher degree of specialization. Illinois offered new courses in the geophysics of mining and in world mineral economics. Arizona offered a new course in industrial relations and South Dakota one in industrial psychology. Penn State added courses in mine dusts, rock mechanics, mathematical analysis of mine layouts, and mine time studies. Wisconsin ventured one in the future of the mineral industry. New courses were restricted mainly to upperclass and graduate students. Fundamental courses in the basic sciences were emphasized more than ever.

The graduate research program, in general, did not receive the attention given to undergraduate work. While scholarships and equipment for undergraduate work in coal mining and foundry, for example, were generously donated, industrial fellowships on the graduate level were relatively scarce and will probably remain so until more schools develop programs that demonstrate ability to conduct research successfully either alone or on a co-operative basis. Heavy academic teaching loads, lack of equipment and space, and still too few graduate students were the primary deterrents. Many employers paid a salary premium for graduates with advanced degrees. With such an incentive and with the inception of graduate work, even though on a modest scale, in many schools, a more vigorous program can be anticipated for the future.

The demand for graduates remained high throughout the year. Schools reported that all of their 1948 graduates were placed and jobs were available in all categories. A few schools believed that opportunities in certain fields may be slightly more limited this year than last and that companies are becoming more selective. Some of the larger mining companies sent personnel officers to the college campus to interview graduating seniors several months before commencement. This is standard practice with many manufacturing companies. The personal contact between the student and the company officer is beneficial to both. The student is impressed by the fact that the company is interested enough in him to send its representative to interview him. He can ask questions about the company which only the personnel officer can answer. His loyalty to the company has its inception at the personal interview. Smaller mining companies might well emulate the practice of certain manufacturers and jointly employ the services of a personnel consultant.

While considerable remodeling was accomplished on numerous campuses, comparatively little construction actually got underway on new buildings for mineral engineering departments. Penn State completed a new mineral industries coal combustion laboratory unit and reported good progress on the construction of its new million dollar Mineral Sciences building. A few other colleges have specific plans for buildings or for legislative requests. In like manner, acquisition of new and modern equipment made some progress but not commensurate with the need. Appropriations and budgets still lagged behind rising costs of equipment and construction.

In view of the progress made during the year, and with students and faculties happier in their work and working more effectively than ever, it seems reasonable to predict that mineral industry education is prepared to meet the greater demands of the next decade.

## Battery School Started

A series of practical one-week schools to teach better techniques of storage-battery maintenance and repair to foremen, supervisors, and engineers in those many industries which employ lead-acid batteries for motive power, standby, or direct current supply, was inaugurated in Trenton, N. J., by Gould Storage Battery Corp., on Nov. 8. Ten representatives from five coal-mining enterprises heard nine lectures, tackled three do-it-with-your-own-hands laboratory projects, witnessed two major demonstrations, stood both written and oral examinations, and received diplomas, during five full days of the first Gould industrial storage battery school.

So successful was this course for coal men (concerned with underground haulage costs) that, according to M. W. Heinritz, vice-president, future five-day schools will be conducted by Gould for additional coal and metal mining groups, as well as for classes interested in (1) battery-powered lift trucks and material handling systems, (2) telephone and other communications systems, (3) railway car lighting, Diesel starting, and air conditioning, and (4) transportation signal work.

**Attending the first session of the Gould storage battery school for electrical engineers and maintenance men are (l. to r. front row): S. Pellerite, Consolidation Coal Co.; M. Sidick, Castle Shannon Coal Co.; J. A. Kalasky, Eastern Gas and Fuel Assn.; J. C. Moore, Harry W. Smith, Inc.; (second row) J. Varson and V. Mullins, Consolidation; A. Obenshain, Republic Steel Corp.; S. V. Malin and K. Marsch, Gould; (third row) P. L. Jones, Eastern Gas and Fuel; A. W. Bitner, Pennsylvania State College; (back row) T. B. Wolfe and J. F. Norris, Olga Coal Co.; A. M. McAfee, Gould.**

# Copper Industry . . .

## . . . handicapped by strikes, pushes expansion; electric melting furnaces popular

By **J. G. LECKIE** • REDUCTION AND REFINING OF COPPER COMMITTEE, AIME

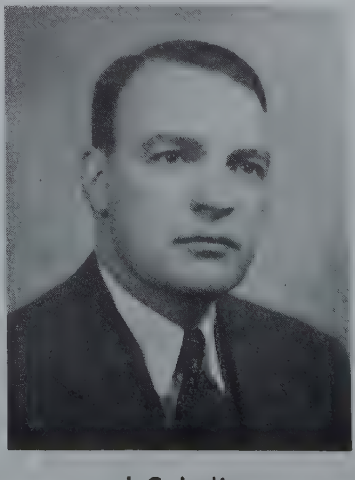
During the first ten months of 1948 copper was produced at a higher rate than in 1947. However, on Oct. 24 one of the large mines was shut down due to a strike. As of Dec. 31 the strike was still in effect and had already resulted in a loss of production of 50,000 tons of copper.

The demand for copper was considerably greater throughout the year than the supply. The price of electrolytic copper delivered at the Atlantic Seaboard refineries advanced from 21.20 to 23.20 cents per lb during the year. This sustained demand for copper, together with the increase in price, has had the natural effect of spurring interest in uncovering new deposits, and in re-examination of known low-grade deposits and old tailing dumps. This is in addition to the usual re-evaluation activities which normally result from the constant improvements in efficiency of ore concentration.

An extensive drilling campaign is planned in a porphyry copper deposit in southern Peru, believed to be potentially one of the most important discoveries of low-grade copper ores in recent years. Exploratory and mill tests of ore on a new property in Ontonagon County, Mich., are being conducted. These are but two of many such activities.

Expansion and modernization in mining, concentrating, smelting, and refining are going on all over the world. The mines at Ray, Ariz., are being converted from underground to pit operation. An electrification project in the open-pit mines at Ajo, Ariz., has been completed. A new 25,000-ton concentrator and smelter is being designed to treat sulphide ores at Chuquicamata, Chile. At Inspiration, Ariz., the capacity of the leaching tanks was increased by raising the walls of all leaching tanks 18 in. to compensate for an anticipated decrease in the over-all grade of mine ore. This operation was completed without interruption to current operations. The railroad from the Bingham mines to the mills at Magna and Arthur has been electrified. Locomotives of 3300 hp are used, each handling a train of seventy 100-ton cars.

A new smelter to treat copper concentrates from the New Cornelia branch is being built at Ajo, Ariz., and is expected to begin operations in 1950. The principal equipment comprises one reverberatory furnace, two converters, and one anode refining furnace. A small smelter of about 6000-tons-per-year capacity is being designed for construction at Tucuman, Argentina. At Superior, Ariz., the reverberatory charge is being changed from roasted material to a wet charge and the waste-heat boiler plant is being modernized.


J. G. Leckie

A 12,000-ton-per-month copper refinery is being built at Garfield, Utah, and is scheduled to begin operating in 1950. An interesting feature of this project is the elimination of all reverberatory furnaces. There will be one 20-ton-per-hour electric-arc furnace for remelting anode scrap and two furnaces of the same size and type for casting refined shapes. The electrolytic cells will be individual monolithic tanks made of reinforced concrete and lined with antimonial lead. An anode casting plant is being constructed at the Garfield smelter to supply anodes for this refinery. The plant will contain four tilting anode furnaces and two casting wheels. A new refinery has been built at Oroya, Peru, and was scheduled to start operations at the end of 1948. Two items of particular interest are the use of mercury-arc rectifiers for supplying the direct current to the tank house and an electric-arc furnace for melting the refined copper. A refinery with an initial capacity of 36,000 tons per year is also contemplated for Northern Rhodesia and is expected to begin operations in 1952.

Typical of modernization in the industry are the improvements being made at a large western plant. Two modern ore-crushing and sampling plants, each of 100-ton-per-hour capacity are being constructed and the transportation and handling facilities are being greatly improved. The program includes a complete dust-control system in the arsenic plant, which will result in a better product and better working conditions. A sulphuric acid plant is under way to produce 100 tons of acid per day from the presently wasted converter gases.

Renewed interest is being shown in the use of acidic ferric sulphate for leaching copper from low-grade ores and tailing. The ferric sulphate is produced from waste ferrous sulphate and waste sulphur dioxide from smelter gas. The ammonium leaching process is still being used in the Lake region for the recovery of copper from tailing and from copper and brass-coated steel scrap.

There seems to be a general tendency throughout the industry toward the increased use of basic refractories. At Hubbell, Mich., small reverberatories (100 tons) built entirely of basic brick are reported to be giving excellent service under the worst possible conditions. The worst drawback is the tendency of the brick to "grow" nonuniformly.

Suspended-brick roofs are being used in the refining furnaces at Jadotville, Africa, and are reported as giving twice the number of charges before it is necessary to shut down for side-wall repairs. Both silica and magnesite brick are being tried in these roofs. Another method of increasing the life of reverberatory furnace brick-work is still being actively pursued. This is the daily spraying of the roofs, side walls, and uptakes with a slurry of fine silica or magnesite, depending on the type of brick being treated. Considerable success is being obtained and although spraying is costly, it is reported that the cost is more than offset by increased furnace life. An important factor in this practice appears to be the consistent periodic spraying rather than doing it sporadically.

Producers of refined copper and copper alloys are becoming increasingly interested in the work on continuous casting which is going on at several plants. This interest received added impetus during 1948 when announcement was made that the steel people were successfully producing steel shapes by this process. At Perth Amboy continuous-cast deoxidized copper billets have been produced since 1937 and further experimental work has resulted in application of the process to the copper-base alloy field. Methods have been developed for the production of tubing and special shapes such as squares, rectangles, and hexagons in either solid or tubular form. Means for casting rods in multiple have made possible the commercial production of sizes as small as 7/16 in. in diameter. At Waterbury, Conn., Junghans-Rossi machines are producing large diameter brass billets and flat shapes for cold rolling, while at Carteret, N. J., experiments are in progress on the continuous casting of tough-pitch copper in the same type machines.

A major development in the production of refined copper is the increased activity regarding electric-arc furnace melting. The first large arc furnace was installed at Copper Cliff, Ont., in 1936 and was followed by a second furnace in 1938. The first large installation in the United States was made at Reading, Pa., and was placed in operation in the early part of 1948. Furnaces are now being installed at Baltimore, at Montreal, at Oroya, and are contemplated at Garfield.

One feature of the electric-melting furnace, which has involved discussion, is the type of bottom to install. At Copper Cliff the bottom is of the "burned-in" type and is installed by slowly fusing gradual additions of periclase mixed with other ingredients to lower the melting point. This requires considerable skill, is a difficult job to perform, requires about six weeks to install, and its initial cost is high. However, when once properly installed, it appears to have almost indefinite life, except for minor repairs, as shown by the fact that the Copper Cliff bottoms have been in over ten years. The furnace at Reading also has a "burnt-in" bottom, while the furnace at Oroya has a rammed-mullite bottom. There has also been considerable discussion regarding the advisability of using a basic-brick bottom.

Experiments on tank-house addition agents are still in progress and have assumed greater importance in view of the reported effect of cathode surface structure on electric-furnace melting practice. Other developments in the industry include a new method of cleaning the tuyeres of copper converters, and the increased use of stainless-steel equipment in the wet-process departments of refineries.

The principal emphasis of the copper industry during 1948 was directed to maximum production at a lower cost. This is confirmed by the large amount of new construction, either planned or completed, by the installation of electric furnaces for copper melting, and the modernization of material-handling methods.

We are indebted to the members of the AIME Committee on the Reduction and Refining of Copper for supplying material for this review.

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## GOLDFIELD GEOLOGY BROUGHT UP TO DATE

In the October number of the University of Nevada Bulletin, Fred Searls, Jr., describes the geologic reasoning which has led to the exploration of an area to the west of the known ore bodies at Goldfield which was formerly believed to be barren of commercial mineralization. This paper brings up to date USGS Professional Paper No. 66 which has been the bible of the geology of this district. Entitled "A Contribution to the Published Information on the Geology and Ore Deposits of Goldfield, Nevada," this paper may be had for 50¢ from the University of Nevada, Reno.

## 200-YEAR-OLD MINE SOLD BY GOVERNMENT

The Petroleum Export-Import Corporation of New York recently purchased a pre-Revolutionary War iron mining property from the War Assets Administration for $700,000. The Ringwood, N. J., property, which cost the Government some $4,000,000, was opened prior to 1740, at which time a blast furnace was first erected there. The Government purchased the 878 acres, including plant and equipment, in 1942, but planned improvements were not completed before the war's end. The new owners will spend $425,000 for improvement and development.

**General view** of the northwestern part of the plant of the American Zinc Co. of Illinois.

# Zinc Industry . . .

## . . . experiments on roasting and smelting; adopts larger sintering machines and vertical retorts

By **R. A. YOUNG** • REDUCTION AND REFINING OF LEAD AND ZINC COMMITTEE, AIME

Zinc metal production in the operating plants in the United States during 1948 was approximately equal to that of the year 1947, although new developments during the year assure higher output in 1949, if economic conditions are favorable. In the Western plants, the man-power shortage was almost completely overcome and new capacity has been or is in the process of being added to three plants; thus by December of 1948 daily zinc metal production had risen to the highest point since May of 1944 despite strikes in one large primary smelter and in one secondary plant.

From a technical standpoint the year brought no radically new developments although experimental work continued on new roasting and smelting processes. The plants which have expansion programs under way are putting in essentially conventional equipment. Other plants are continuing to modernize with new equipment and, particularly, labor saving devices as more materials become available.

### roasting and sintering

In the roasting of zinc concentrates the fluidizing process of the Dorr Co. continued to produce interesting results on zinc sulphide concentrates, although the process is still in the laboratory stage. The use of oxygen in the Trail suspension roaster at the Consolidated Mining and Smelting Co.'s plant at Trail, B. C., is understood to yield considerably higher tonnages. It is interesting to note that in their expansion programs both the St. Joseph Lead Co. at Josephtown, Pa., and the New Jersey Zinc Co. at Palmerton, Pa., are installing Trail-type suspension roasters. Originally these plants used different types of roasters, hence the further adoption of the Trail-type roaster for electro-thermic and vertical-retort smelting seems quite significant. At the St. Joe plant two Trail-type roasters were started in March of 1948 and are reported to be operating on a most satisfactory basis. While the capacity of the conventional Trail roaster has been nominally 100 tons per day, St. Joe has found that it can reach a capacity of 150 tons per day in the new plant. This Company now has a total of four contact acid units in connection with the roasting department. The New Jersey Zinc Co. at Palmerton is adding a contact acid plant which will operate in conjunction with the new roasters.

In the sintering of zinc ores the trend has been to wider and longer machines, and some interesting plants equipped with these larger machines are now being completed. At Prayon, in Belgium, there is being installed a machine which is 3½ m wide and 23 m long over the wind boxes. The feed to this machine is to be raw zinc concentrates and the gases will be sent directly to the sulphuric acid plant. The machine employs sliding pallets on rails, and the new pallets will have side members of forged steel finished by machining and cross members of structural steel. St. Joe at Josephtown now has six modified sintering machines which are 60 in. wide with sloping side-bar pallets traveling over a 44-ft wind box. Extensive experimentation at this plant has developed a large-diameter drum-type mixer which reportedly achieves a superior mixing and pelletizing action. The New Jersey Zinc Co. is also adding to its sintering capacity at Palmerton.

## gas precipitators

While no radical changes have been made in methods of collecting solids from sinter-plant gases, there have been some interesting developments. Ultrasonic precipitation of solids from sinter-plant gases is arousing interest. However, installations for metallurgical applications on lead oxide, molybdic oxide, and molybdic sulphide have been reported and the company producing this equipment feels that it is entirely feasible to use this process to good advantage on the collection of solids from sinter-plant gases. The American Metal Co., at its Blackwell, Okla., plant which has been using an old-type tube and wire-Cottrell precipitator, is now planning to replace this with a conventional-type baghouse. On the other hand, St. Joe has a 350,000 cfm rod-curtain-type Cottrell at its new sintering plant at Josephtown.

The development of a new transistor by the Bell Telephone laboratories, which depends on a small crystal of metallic germanium to replace the old complicated vacuum tube, has resulted in an intensive search for new sources of germanium metal in zinc-sintering-plant by-products. Although several companies are pursuing this search diligently, no announcement of results had been made.

## reduction and volatilization

The industry is watching with considerable interest the work of the Pend Oreille Mines and Metal Co. which has leased the Mead magnesium plant in the State of Washington and is experimenting on vacuum distillation of zinc.

An interesting piece of work was published in August by the Bureau of Mines covering firing schedules, influence of conditions of combustion, nature of retort charge, and burner design for horizontal retorts. These reports covered co-operative work done between the Bureau and the Eagle-Picher Mining and Smelting Co. No new equipment changes have been reported except that mechanical clean-out of retorts, which has been employed for a good many years, has been adopted by at least one additional plant in the industry. Other companies have made small changes in procedures aimed toward labor saving or increased furnace charge per man-shift. In the natural gas belt of the Southwest, all plants except one remained on a 48-hr firing cycle, and this one plant adopted a part-time 36-hr cycle. In the coal-producer fired furnaces east of the Mississippi River, the three plants remaining in operation continued the conventional 24-hr firing cycle.

R. A. Young

The vertical-retort plant of New Jersey Zinc at Palmerton is being expanded. No significant changes in this process were announced during 1948.

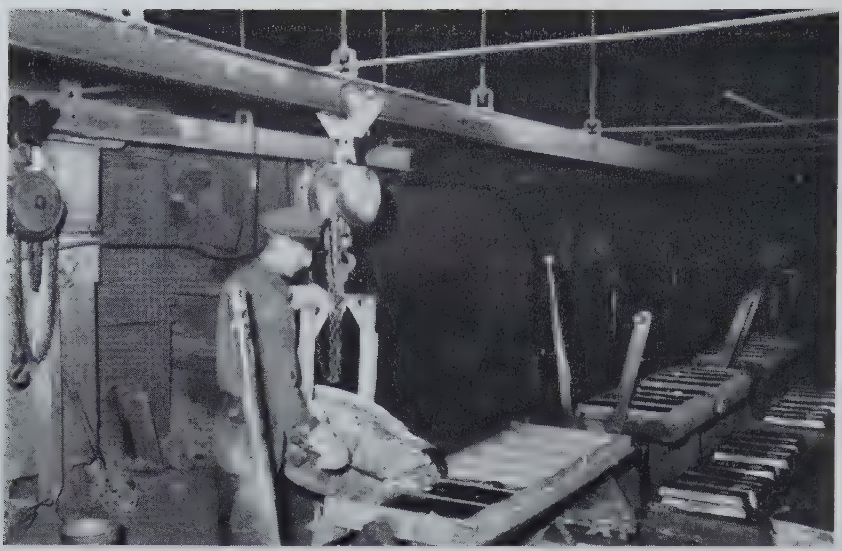
The St. Joseph Lead Company at Josephtown, completed four new electrothermic furnaces this year. These are of improved design, being 8-ft internal diameter and having a greatly increased zinc-vapor capacity. This increase of capacity has necessitated the modification of the standard Weaton-Najarian condenser. Much experimenting has been done with double-tube condensers although final design has not yet been settled. During the interim period, the Company reports that each of these furnaces is equipped with two conventional condensers operated in parallel. The four new furnaces were designed for a zinc metal production rate of thirty tons per day but actual experience has proved that a steady production of forty tons per day can be achieved.

## electrolytic recovery

In the electrolytic-reduction field the expansion of the Sullivan Mining Co. at Silver King, Idaho, and the decision of the Hudson Bay Mining and Smelting Co. at Flin Flon, Manitoba, to install facilities for reclaiming zinc from electrolytic-plant residues and reverberatory slag are of particular interest.

Increased mine production of zinc in the Coeur d'Alene district of Idaho, plus the increasing demand of consumers for special high-grade zinc, has prompted the Sullivan Mining Co. to start the addition of a fourth electrolytic unit to the existing three electrolytic units they are now operating. While this unit is now adding some to the capacity of the existing plant it will not be brought into full operation until 1949 and will bring the capacity of the plant to about 50,000 tons per year of special high-grade metal.

It is reported that the Hudson Bay



**Decreased production** of common grade zinc may become an industry problem.

Mining and Smelting Co. has decided to spend $6,000,000 for a zinc-fuming plant to reclaim, as crude oxide, zinc from electrolytic-plant residues and reverberatory-furnace slag. The crude oxide so produced will be returned to the electrolytic-zinc circuit for the recovery of the zinc content as electrolytic metal. It is reported that the plant has an accumulation at the present time of approximately 800,000 tons of residues.

Another installation of interest is that of the new fume scrubber employed by the American Zinc Co. of Illinois, at its Monsanto, Ill., plant on the cathode-melting furnace. This installation is somewhat of an innovation in that it is a wet collection in an obnoxious-vapor condenser of the fume from the melting of cathodes with the resulting slurry being acidified and returned to the zinc circuit. This installation is reported to be highly efficient.

## secondary zinc

At the East Chicago plant of the Eagle-Picher Co., French-process zinc oxide is still made from die-cast and other types of zinc scrap. This company has also entered into the production of zinc dust from galvanizers' dross at the East Chicago unit. The American Zinc Co. of Illinois has installed and is operating at Hillsboro, Ill., a muffle-type furnace which is presently being used for the production of metallic zinc but which, with certain modifications, can be made to produce French-process Zinc oxide. The use of the Wilkins-Poland electric furnace for the recovery of zinc and copper from brass scrap was extended to new operations.

It is interesting to note the slow evolution through which the zinc-smelting capacity of the United States is going and the effect that this evolution has had and will have on the purity of zinc metal produced. The trend in the industry, as capacity-changes take place, has been tending strongly to production of higher purity metal; namely, high grade and special high grade. While the horizontal-retort smelters west of the Mississippi River have been expanded materially since 1940, the increase in this group has been more than offset by the closing down of high-cost uneconomic horizontal-retort plants in the coal belt east of the Mississippi River. Thus, in 1948, despite the fact that over-all production of zinc was some 18 per cent above the 1940 level, the production of the common grades of metal—that is, those other than high grade and special high grade—were actually 6 per cent less in 1948 than in 1940. On the other hand, the production of high-grade and special high-grade metal, which in 1940 comprised only 40 per cent of our entire production, in 1948 was approximately 52 per cent of the production. What is even more significant is that the tonnage produced was approximatelv 52 per cent more than the production of the same grades in the prewar years.

All of this adds up to the fact that despite our appreciable increase in zinc capacity and production since before the war, the capacity for producing Prime Western and other common grades of metal has actually been reduced, and, although the general production level and zinc consumption of our general economy is appreciably higher now than before the war, the amount of common grades available is less. This trend was continued during the year 1948, in which year the production of common grades of metal was below the 1947 level. The new capacity recently built and presently being built is generally of the type which can produce the higher grades of metal. If this situation continues in the future as it has in the past, and there is every reason to expect that it will, it makes one wonder if the common grades of metal will not become insufficient to supply the demands of the galvanizing industry and thus cause a serious discrepancy between demand and supply. Of course, the higher grades of metal can always be debased with relatively small amounts of lead and cadmium, but with these metals currently selling at higher prices than zinc it does not seem reasonable that producers will be too willing to do appreciable amounts of such debasing without compensating payments therefor. While this situation is not yet serious, it may well pose an interesting problem to the industry in years to come.

The chief public notoriety received by the zinc industry during 1948 was the occurrence of the death-dealing smog at Donora, Pa. As reported by the press, this smog, which resulted in the deaths of nineteen persons, was the result of the smoke from a multiplicity of industry. While the zinc smelter at Donora voluntarily shut down until after the atmosphere could be cleared, authorities reported that they could not directly trace the disastrous results to any one plant or industry, and operations at the zinc smelting plant were thus resumed. While a great deal of unfortunate publicity was given to the zinc plant during this disaster the health authorities reported that they could not place any more responsibility for the occurrence on the smelter than on any other industry.

# Lead Metallurgists . . .

## . . . mechanize smelters abroad, improve dust control, study furnace design in smelting and vacuum dezincing process in refining

By **W. T. ISBELL** • REDUCTION AND REFINING OF LEAD AND ZINC COMMITTEE, AIME

Although the pressure to meet the heavy demand for lead still took precedence over new metallurgical developments in the field of roasting, smelting, and refining of lead in 1948, there nevertheless has been considerable activity in the experimental development of new processes and improvements as well as plans for the modernization of many plants both here and abroad. Increasing labor and material costs have stimulated the trend to greater mechanization, revamping of flow sheets, and construction of larger units wherever possible.

Although there have been many serious labor stoppages in the United States, Mexico, and Europe, labor supply has improved in most plants even if it has fallen off in efficiency.

### roasting and sintering

Unloading and handling of concentrates, ores, fluxes, and fuels have received a lot of attention, especially in Mexico where labor costs have risen. The Chihuahua and San Luis Potosi smelters of the American Smelting and Refining Co., as well as the Torreon smelter of the Cia. Metalurgica Penoles, have mechanized and adopted mechanical gadgets to fit in with existing plants in an effort to reduce the need for labor as well as to improve working conditions.

Charge preparation for roasting and sintering has received a lot of attention at most smelters. Smelter men have recognized the importance of sizing and blending of material before sintering, but little was done about it during the war when maximum production was desired and materials and labor for changes were almost nonexistent. The Selby plant is installing a new ore-handling and bedding system. The Leadville plant is installing a new Cottrell and improving their sinter plant.

The pilot plant at Trail for nodulizing lead concentrates and zinc-plant residues is giving a better final sinter and greater tonnage per hearth area and will, no doubt, be incorporated in the new lead smelter. Other investigators have found that the addition of lead sulphide concentrates to "solid oxygen" materials, such as sulphates, oxides, etc., either as lead bearing materials or fluxes prior to the formation of pellets or nodules greatly increases the tonnage from the sinter machines as well as improving the final sinter.

At one plant a new method of laying down the charge on the D&L machines shows considerable promise of increased tonnage and improved product. Where new D&L machines are being considered the tendency is to wider and longer machines. One plant is considering a 12 ft wide machine. The Selby plan of AS&R is putting in a new sinter crushing plant and an additional 63-in. D&L machine. The Herculaneum smelter is now installing a 72-in. D&L machine for primary roasting along with a cooling table, and crushing and sizing equipment. It is planned to replace the present 42-in. machines with the larger ones.

Recirculation of D&L gas is also being considered by many of the smelters. The Selby plant has been doing this for sometime and their liquid sulphur-dioxide plant has been operating for about a year producing 15 tons of liquid per day. This supplies the bulk of the California market. At San Luis Potosi, a 50-ton sulphuric acid plant has been constructed and the setup for recirculation of D&L gas in order to obtain a 6 per cent sulphur dioxide has been practically completed.

Sulphuric acid produced by the recirculation of D&L gas is black in color, due to the presence of about .02 per cent colloidal carbon which acts as a dye. The Selby plant has perfected a clarification process which consists of electrolyzing about 1/50 of the acid output in a diaphragm cell for the production of sufficient hydrogen peroxide to oxidize the small amount of carbon present.

**Two familiar scenes** at the lead smelter which are not changed by recent progress in technology.

D&L gas is being recirculated at the Baelen lead smelter, Vielle Montagne, in Belgium, on a 2 m wide and 13 m long D&L machine. Gas from 4.5 to 5 per cent sulphur dioxide is purified and then goes to Peterson towers for conversion to sulphuric acid (60° Bé).

Collection and treatment of lead fume has received attention during the year. The Bunker Hill smelter is installing an Ultrasonic Corporation pilot plant for the recovery of fume. This plant was expected to be in operation by late 1948.

Roasting for cadmium concentration in lead fume was initiated early in 1948 at El Paso. A Godfrey 22-ft roaster is used for this purpose. Blast-furnace bag-house dust carrying 5 to 10 per cent cadmium is treated to produce a 50 to 60 per cent cadmium product; this requires further treatment for recovery of the cadmium as metal.

A small leaching plant is being constructed at the Murray plant, AS&R, for the recovery of thallium sulphate from lead fume. This should be in operation by the end of 1948.

## smelting

The shaft furnace for smelting is one of the metallurgist's ancient devices, but there is still no general agreement on its proper shape and size. J. S. Stewart has applied for patents on a lead blast furnace of unusual design based on his theory and experience. However, up to the present time no one has built a furnace of this type.

At the Chihuahua smelter, construction of a new large blast furnace of the type developed by the Broken Hill Associated Smelters, Ltd., at Port Pirie, Australia, was started and should be in operation about the middle of 1949. It will serve as an experiment in determining the merits of this type of blast furnace for the purpose of smelting increasingly higher lead concentrate charges.

At the Trail smelter, experiments with wider furnaces are still being conducted. Latest reports indicate that the 90-in.-wide furnace is operating well. At this plant the use of oxygen tends to smooth out the blast-furnace operating irregularities and a small but important coke saving is indicated. Trail has considered the possibility of using a slag-trap spout and tests on this device have been so favorable that their large blast furnaces will be so equipped.

The Boliden Mining Co. at Skelleftehamm, Sweden, placed a new electric furnace in operation in June for the direct smelting of high-grade lead concentrates. These concentrates are first roasted down to about 6 per cent sulphide sulphur and 4 per cent sulphate sulphur, on two eleven-hearth furnaces, roasting 120 tons per day. Roasted product along with flue dust is charged into the electric furnace. Power consumption is about 350 kw per ton of charge. Slag fall from the furnace approximates 200 kg per ton of bullion. Matte is blown in a convertor for half an hour yielding rough lead which is then sent to the refinery. Latest reports indicate that operations are extremely satisfactory.

A new zinc fuming plant was placed in operation early in September at El Paso. This plant is similar to the ones at Trail, East Helena, Tooele, and Bunker Hill, but it is larger and currently treats 700 tons of 11 per cent slag per day. The fume is deleaded and densified before shipment to retort plants. A 5000 kw steam turbine is used for waste-heat recovery.

The use of oxygen in the slag fuming furnace at Trail permits operation at higher bath temperatures while maintaining optimum reduction conditions. As a result, the rate of zinc elimination from the charge is improved.

Coke used in deleading lead-bearing zinc fume from lead blast-furnace slag blowing has proved successful at the Tooele plant. Small percentages of fine coke mixed with the feed to the deleading kiln along with careful temperature and draft control have produced excellent results. At this plant, mechanical knocking of steel cooling tubes used in the cooling system has done away with all hand labor.

Granulation of blast-furnace and dross-reverberatory speisses by water and air has been perfected at Tooele so that it is possible to roast them in combination with iron concentrates for arsenic elimination without grinding.

Power shortages and the strike seriously interferred with the continuous operation of the Herculaneum slag stripping furnace. However, the furnace was operated for several months with good results. Refractories on the sides of the furnace are eliminated and the furnace operates with water-cooled sides. The carbon bottom is standing up well. Better coke distribution has resulted in improved operating and metallurgical results. Power and electrode consumption is quite satisfactory; reduction of iron in slag is controlled. About half the lead in slag is recovered as metal and the balance as blue powder; most of the copper reports in the matte which is returned to the lead plant. There was no trouble in producing a good quality of prime western zinc.

Although many refractories have been tested for the sides of the furnace, none has stood up; the elimination of these refractories has resulted in somewhat lower tonnage through the furnace. However, plans are being made to widen the furnace at some future time in order to correct this.

Eagle Picher is building a reverberatory furnace for the continuous smelting of battery scrap and other secondary lead material at their East Chicago plant. This will replace the rotary furnace now used. Reverberatory furnaces yield a much cleaner lead which in turn results in a much lower circulating load of dross and by-products to be resmelted. Eagle Picher also placed in operation a Ready-To-Use paint plant and a lead oxide plant at East Chicago.

## lead refining

The Bunker Hill smelter is putting in the continuous softening process as practiced at Port Pirie. The new vacuum dezincing process was put in operation in September at the Selby plant. This process has proved successful in removing zinc from kettle batches of 200 tons of desilverized lead. The Port Pirie refinery is also experimenting with this process and other refineries are considering it. A. Tonollie and Co. near Milan, Italy, have perfected a new process for the electrolytic refining of lead in a sulphamate bath. They claim 99.992 per cent purity of lead produced.

## industrial hygiene

Outstanding examples of progress in industrial hygiene are the American Smelting and Refining Company's various plants, especially the Alton plant, the American Brake Shoe Company's plants, and the Herculaneum smelter. These companies have gone to considerable expense to eliminate dust and to protect workers against the toxic effects of lead. They have set up separate departments with capable personnel and well equipped laboratories for the study and control of lead hazards.

At the Alton smelter, baghouse dust originating from the Scotch hearth furnace is burned in the cellars and then, after thorough wetting, is loaded by means of a caterpillar-tread power shovel. Boxcars containing lead concentrates are ventilated by introducing washed and cooled air through a retractable duct projecting through the door of the car.

Washed and cooled air is supplied to the operators of the Scotch hearth furnaces at a rate of 4000 cfm per 8-ft furnace. The crushing and sampling unit as well as the sample bucking rooms have all been carefully hooded to take care of dust. Dust on floors around smelting furnaces and baghouses has been practically eliminated by spraying with a mixture of one-third kerosene and two-thirds fuel oil. Portable vacuum sweepers are used daily to clean the floors.

To eliminate dust arising when fine dry material is dumped into a pit prior to wetting down, the pit is provided with a cover and a small baghouse. In places where the dependability of a respirator is doubtful, fresh-air masks are proving satisfactory. Where the regular plant source of compressed air cannot readily be used, then a cylinder of certified pure air provides an excellent source of supply.

## JANUARY ISSUES OF THE JOURNALS

Institute headquarters has received a few letters from members who received the February issue of the journal of their choice but, at time of writing, had not received the January issue. This complaint comes largely from those who made their publication selection late in December or early January. In such cases, wrappers were sent direct to the printer for second-class mailing in bulk of the February issues, but the January issue had to be mailed individually by third- or fourth-class mail from Institute headquarters, and so was subject to delay.

All members who have paid their dues and made a selection of the journal they wish to receive are entitled to receive *every* issue, beginning with January. If they did not receive the January issue, or if they did not receive the February issue within say a month after paying their dues or within a month after publication, a postal card to Institute headquarters will bring the matter to our attention.

Publication dates are approximately as follows: for "Mining Engineering" about the first of each month; for the "Journal of Metals Technology • Practice," about the fifth; and for the "Journal of Petroleum Technology" about the fifteenth. Regular second-class mailings of the first two (except for the metropolitan New York area) are from Philadelphia; for the petroleum journal from Dallas.

**Aluminum aids the home builder.** A carpenter can lift aluminum siding, weighing 100 lb, while lumber would weigh about 400 lb.

# Aluminum Metallurgy . . .

## . . . makes progress in welding but industry hampered by metal shortage

By PAUL P. ZEIGLER • DIRECTOR, METALLURGICAL RESEARCH DIVISION, PERMANENTE METALS CORP.

Rapid growth of the aluminum industry continued through 1948 with an acute shortage of the metal in all forms marking the year. Estimates based on shipments made during the first nine months indicate that, in 1948, the industry shipped more than two billion pounds of aluminum products or roughly four times the amount shipped in the greatest peacetime year prior to the war. The rapid expansion of the aluminum industry is particularly reflected in the production of sheet. Last year, the industry as a whole shipped an estimated 40 per cent more sheet than was produced in the peak war year of 1944.

This phenomenal growth dates from approximately the year 1939 but substantial expansion occurred during the years 1936 to 1939. In the course of four years during the war, the industry expanded its primary ingot production facilities sixfold. Even though the industry found that a portion of the facilities expanded for military purposes could not be operated cheaply enough to compete in our peacetime economy, the national capacity for economic production now remains four times that of 1939. No other major metal experienced anything resembling this amazing development. While capacity for primary aluminum production increased 400 per cent, the nation's capacity for steel production rose 11 per cent; copper refining capacity increased only 3 per cent; lead, 16 per cent; and zinc, 57 per cent.

According to the estimates for 1939, 1947, and 1948, the use of the metal in 1948 increased over its use in 1947 in all the major categories shown in the accompanying table.

These estimates indicate several significant changes in the relative consumption of the various categories for the years 1947 and 1948 as compared with 1939. Whereas the transportation industry was the largest consumer in 1939, with power transmission and building products second largest and smallest, respectively, building products accounted for the greatest consumption in 1948 with the transportation industry second largest and power transmission smallest. A similar consumption pattern existed in 1947.

In 1948 the Aluminum Co. of America began the construction of a reduction plant at Port Comfort, near Port Lavaca in Texas. The nationwide shortage of electric power being the basic cause of the present shortage of aluminum, Alcoa, in conjunction with the Nordberg Mfg. Co., developed special internal-combustion gas engines to generate the necessary electric energy. Thus, power at the Port Comfort plant will be generated by 120 1000-kw radial-type two-cycle spark-fired internal-combustion engines using natural gas as fuel. Alcoa's new sheet and plate mill at Davenport, Iowa, came into production during the year. This mill rolls an ingot weighing approximately 7000 lb which represents a 100 per cent increase over sheet-ingot sizes normally rolled by any other of the previously constructed aluminum sheet mills throughout the world.

During the year, the Permanente Metals Corp. announced the acquisition of two important new manufacturing facilities. They were a German foil mill which is now being installed at Permanente, Calif., and a rod and bar mill at Newark, Ohio, where equipment for the manufacture of steel-reinforced aluminum-conductor cable is being added. In addition, the Company's new metallurgical research laboratories located at Trentwood, Wash., achieved substantially full operation by the end of the year.

Both Reynolds and Alcoa introduced pattern aluminum sheet to the market last year. Although pattern sheet is now being used mainly on industrial and institutional buildings for exterior wall facing and roofing, the versatility of pattern design indicates much broader potentialities for both decorative and functional uses in many industries.

The first experimental, field-welded, aluminum pipe lines were laid last spring for the Interstate Oil Pipe Line Co. in the vicinity of Magnolia, Ark., and Raceland, La. The project consisted of a half mile of 4 in. IPS line, and two sections each of 4-in. IPS line approximately one quarter of a mile long. A portable inert-gas, shielded arc welder was used to join the alloy pipe.

The Air Reduction Co. disclosed an important new modification of shielded arc welding. The new process consists of feeding a bare or processed filler-metal wire through a suitable holder. With the filler-metal wire carrying the welding current, a d-c arc is maintained between the end of the wire and the work. As in other shielded arc processes, the arc is contained in an envelope of inert gas. The new method offers possibilities of satisfactorily welding thicker aluminum-alloy plates than have hitherto been successfully joined by other welding processes. It also enables vertical and overhead welding.

In the finishing trades, electrobrightening gained increased popularity. The Colonial Alloys Co. and the Philadelphia Rust-Proof Co. began exploiting bright chemical etching or chemical polishing processes.

Aluminum - magnesium - zinc alloys, and 75S, in general, continued to engage the attention of many investigators. Mott and Thompson reported on an extensive study of ternary aluminum-magnesium-zinc alloys with minor additions of manganese or chromium or both. Their results indicate these alloys to be more sensitive to stress-corrosion cracking than the commercial aluminum alloys when suitably heat treated.

M. G. Fontana and J. L. Zambrow

CONSUMPTION OF ALUMINUM BY INDUSTRIES

| | 1939* | | Estimated 1947 | | Estimated 1948 | |
|---|---|---|---|---|---|---|
| | Million Pounds | Per Cent of Total | Million Pounds | Per Cent of Total | Million Pounds | Per Cent of Total |
| **Building products** | 13 | 3 | 589 | 32 | 769 | 37 |
| **Transportation** | 86 | 19 | 295 | 16 | 312 | 15 |
| **Air** | 51 | 11 | 110 | 6 | 187 | 9 |
| **Autos and trucks** | 22 | 5 | 168 | 9 | 104 | 5 |
| **Others** | 13 | 3 | 17 | 1 | 21 | 1 |
| **Cooking utensils** | 31 | 7 | 127 | 7 | 166 | 8 |
| **Machinery and applications** | 37 | 8 | 184 | 10 | 229 | 11 |
| **Power transmission** | 57 | 13 | 127 | 7 | 146 | 7 |
| **Export** | 101 | 23 | 156 | 8 | 104 | 5 |
| **Others** | 112 | 25 | 370 | 20 | 354 | 17 |
| **TOTALS:** | 449 | 100 | 1848 | 100 | 2080 | 100 |

*War Production Board

Paul P. Zeigler

studied the mechanical and physical properties of some aluminum alloys at elevated temperatures and subnormal temperatures extending to minus 423F. They found that the notch-bar impact strengths of 2S, 24S-T4, 61S-T6, and 75S-T6 are not impaired at minus 423F and that the tensile properties and creep characteristics of 24S-T4 at 600F are equivalent or superior to 18S-T6 and 32S-T6.

Webster Hodge, L. W. Eastwood, C. H. Loring, and H. C. Cross obtained excellent elevated-temperature tensile properties and improved creep characteristics at 600F in an aluminum-base casting alloy containing 6 per cent magnesium, 1.5 per cent copper, 1.0 per cent manganese, and minor additions of zirconium, boron, titanium, and beryllium.

## Stock Pile Needs

An active Federal Government stock-piling program has brought a call for strategic and critical minerals, including: chrysotile and amosite asbestos, bauxite, beryl, bismuth, cadmium, metallurgical and battery grade manganese, film moscovite, steatite block talc, and zinc. Producers should submit an offer, in letter form, stating price, quantity, etc., of materials available before June 30, 1949. A "Suppliers List Application" is obtainable at the Bureau of Federal Supply offices of the Treasury Department. It places you or your firm on a government suppliers' list.

Specifications for the above listed materials can also be obtained from the same address.

**Only one pass** of the torch is necessary to arc weld this ½-in. magnesium floor plate.

# Magnesium Industry . . .

## . . . improves manufacturing techniques sufficiently to compete with aluminum; metallurgical progress in electroplating, welding, brazing

By **J. D. HANAWALT** • REDUCTION AND REFINING OF ALUMINUM AND MAGNESIUM COMMITTEE, AIME

Significant strides were made in the year 1948 leading to further recognition of the place of magnesium as a common commercial metal, rather than as just a premium aircraft material. One of the factors contributing to this recognition was the price stability and, in many cases, price reduction of magnesium products in 1948. In contrast to most other metals, manufacturing advances in magnesium outweighed the effects of increased labor and other costs. At the present time, many magnesium extrusions, die castings, and permanent mold castings can be purchased as cheaply as their aluminum counterparts in these forms, though competitive prices for sheet still await the inauguration of a modern tandem rolling mill for magnesium, such as has already been demonstrated.

Increasing appreciation of the basic availability of magnesium was another major factor assisting in the recognition of magnesium as a common commercial metal. The practically infinite supply of high-grade uniform magnesium ores in both land and sea has come to be well recognized, but it took the present-day shortage of electrical power and the consequent limitation on the production of aluminum metal to focus attention on the fact that to produce the same volume of both metals, magnesium requires only two thirds as much electrical energy as aluminum. For quick expansion of metal supply, such as would be required in a national emergency, magnesium can be produced by the ferrosilicon reduction process for one third of the electrical energy required to produce an equal volume of aluminum metal. In 1948, all primary magnesium in the United States was produced from sea water. However, it is interesting to note that the original ferrosilicon magnesium plant is scheduled to be reopened in Canada early in 1949.

Among the important metallurgical developments in magnesium in 1948 should be mentioned the electroplating of magnesium. While many attempts to electroplate magnesium have been made, it is only in the last year that a process has been announced which is competitive and which has proved serviceable in both interior and exterior exposures. The process consists in the initial application of an immersion zinc coating, followed by a copper strike, and then electroplating with any of the usual metals from standard plating baths. The zinc-immersion bath is a solution of tetrasodium pyrophosphate with additions of zinc sulphate, potassium fluoride, and potassium carbonate. Analysis of the immersion coating formed on the magnesium shows it to be metallic zinc.

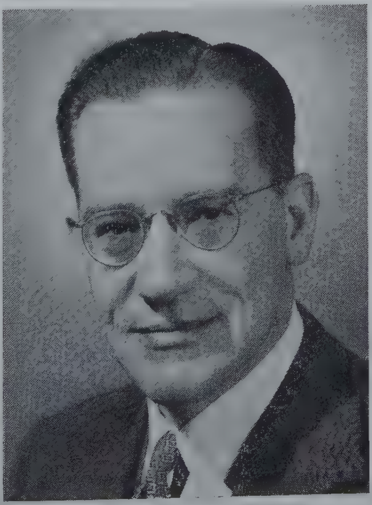
Two distinct advances in the technique of joining attained a practical state of development in 1948, and have found utility. It is now possible with inert gas-shielded arc welding of magnesium to make single-pass welds in heavy plate. The proper choice between a-c and d-c equipment is largely dependent upon the thickness of metal to be welded. Direct current, which was first used commercially on magnesium, is best suited for welding sections up to about 3/16 in. Recently, the use of alternating current with a high-frequency stabilization current superimposed on the normal welding current has been introduced. With alternating current, single-pass butt welds can be made in magnesium plate over ½-in. thick without requiring any bevelling or spacing of plates. For welding thin sheet, both a-c and d-c equipment are satisfactory.

The brazing of magnesium has attained production status in 1948. The three methods of brazing employed are: furnace, flux dip, and torch brazing. The process is used with Mg-1.5-Mn alloy and the filler metal is Mg-9Al-2Zn, sometimes with the addition of a small amount of beryllium. Modified gas-welding type fluxes are used. Brazing temperature is 1130 to 1180F, and the strength of the brazed joint is equal to that of the metal.

Intensive investigation of new alloys of magnesium and their properties is evident in a review of the literature in 1948. These investigations take several directions. Considerable headway is being made in the direction of improving the properties of magnesium alloys at the increasingly elevated temperatures attained in the magnesium parts of modern jet engines. Creep limits of cerium-containing magnesium alloys at 400F are tenfold higher than those of the common Mg-Al-Zn type alloys. New alloys of magnesium containing zinc plus zirconium or manganese have intermediate creep limits at 400F, while showing good strength properties at room temperature. The thermal conductivity of these cerium and zinc alloys is about twice that of the Mg-Al-Zn type. The practical foundry characteristics of the Ce-Zn alloys are now being worked out on production scale castings. Another direction of alloy development which is in only the laboratory stage, but which seems to give indication of high strength values as well as other unique characteristics, is the development of lithium-containing magnesium alloys.

Grain refining techniques are of importance in the casting of magnesium alloys. Definite advance in the theory of grain refining is seen in the report of the isolation and identification of several nucleating agents.

Other important metallurgical developments which have been reported include magnesium-anode dry cells of high capacity and superior low-temperature performance patterned after the conventional Leclanché cell used for flashlight batteries. Also reported is the alloying of about 0.1 per cent magnesium with cast iron with resultant properties of greater than six per cent elongation and greater than 80,000 psi tensile strength.



J. D. Hanawalt

Many new and important developments in the utilization of magnesium have reached a practical stage in the past year. While magnesium had previously been utilized as an anode in the ground to protect pipe lines from corrosion, it has now been extensively adopted by the principal water-heater manufacturers as an anode placed inside their tanks to insure longer life. The technical problems involved in using magnesium in the photoengraving shop in place of zinc or copper are being rapidly overcome. In addition, good printing characteristics of magnesium have been developed, and an increasing number of newspapers and books are being completely printed directly from magnesium engraved plates, thus eliminating stereotype or electrotype plates. An interesting development in a magnesium die-casting application which has recently come on the market is a folding chair. The three magnesium die castings comprising the chair weigh five lb. and replace 14 separate wooden parts weighing a total of ten pounds in the previous model. Magnesium made considerable headway in truck transportation applications in 1948. Beside magnesium van panel bodies in commercial operation, experimental parts such as wheels, hubs, and brake shoes are being evaluated on the highway.

In spite of the new applications of magnesium appearing in the industrial and consumer fields, the largest single use of structural magnesium in 1948 was still the aircraft industry. While continuing to be the principal light metal for wheels and jet-engine parts, magnesium made considerable headway in use in air-frame parts. Ten per cent of the air-frame weight of the B-36 is magnesium, and the technique of monocoque construction with magnesium is being employed in the newer high-speed planes.

# Industrial Minerals . . .

## . . . find broader markets, set production records, have prosperous year

By G. W. JOSEPHSON • INDUSTRIAL MINERALS DIVISION, AIME

Not only did 1948 bring generally prosperous conditions and technical advancement to the nonmetallic mineral industries, but also notable modifications in some methods of establishing prices. The general prosperity has been reflected in high production of nearly all of the nonmetallic mineral commodities during the past year—many production records were attained. The markets for nonmetallics continued to grow broader.

Real progress was made in stock piling of some strategic industrial minerals, but shortages delayed other purchase programs. Under present conditions, lack of progress in stock piling caused serious concern, and more aggressive purchase policies were adopted.

Legal developments were dominated by the Cement Institute decision handed down by the Supreme Court. This decision promises to have a strong influence upon the pricing practices not only of the producers of cement but of most other commodities. The Morton Salt decision likewise may have a wide effect.

In recent years quite a few nonmetallics have been added to the list of minerals for which depletion allowances have been approved by Congress, and more petitions were presented during the past year.

Among the most useful reference books on industrial minerals has been "Industrial Minerals and Rocks." The commodity chapters of this volume are being revised and in some instances expanded by specialists, and it is expected that the book will be printed and distributed some time in 1949.

Comprehensive discussion of developments in all of the nonmetallic mineral industries is not possible in this brief review, but some trends and developments are outlined in the following sections.

### abrasive materials

During the past year there has been a high output of the artificial abrasive materials silicon carbide and aluminum oxide. Demand for garnet, emery, tripoli, and pumice is also reported to have been good.

Among those with price-policy problems during the past year were the producers of artificial abrasives. A number of the firms and a trade association were cited by the Department of Justice in a suit charging price fixing in violation of the Sherman Antitrust Law.

Although the market for corundum in the United States was far from satisfied in 1948, the future status of this mineral was in some doubt at the end of the year. Our supplies have been coming almost entirely from southern Africa in recent years. The African producers have not been able to supply adequate quantities; consequently, consumers would welcome development of additional sources of supply. Efforts were being made to find sources of commercial size in the Western Hemisphere.

Among the new types of lightweight products reported is a material called pumicell, developed by the Oklahoma Geological Survey. Pumicell is said to be produced by heat-treating pumice to 2160F or more, at which temperature the material expands still farther. It is reported that the material can be made into building-brick slabs weighing 18 to 56 lb per cu ft and having a maximum strength of 2400 psi.

### aggregates

As noted in last year's Review, lightweight aggregates are taking a larger portion of the aggregate market from year to year in the United States. When properly made, they have adequate strength, and the reduction their use permits in the weight of structures can provide substantial savings in cost through improvement in design and reduction of labor. This market has revolutionized the use pattern of the pumice industry. Vermiculite is a preferred type of lightweight aggregate for many uses; but supplies from domestic sources are none too large, and therefore vermiculite produced in South Africa is finding a receptive market in the United States.

Many companies have participated in the perlite development program; some have become discouraged, but

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**Loading** sulphur in Texas.

as the commodity has low unit weight and other attractive properties, when properly made, interest is high in the West. Construction of a plant to expand perlite in Pennsylvania was announced. The rock is to be shipped from the West for expansion in the consuming area, as is done with vermiculite. The gypsum industry has indicated that the market for the lightweight aggregates, such as vermiculite and perlite, for use in gypsum wallboards, is potentially large. The industry has not yet been able to explore this market fully owing to lack of adequate supplies of aggregate. Shale associated with coal beds is reported to be used in the production of a new lightweight aggregate called "Lelite."

The firms that probably are in the best position to produce low-cost lightweight aggregate are those in the iron and steel industry, which still have large tonnages of waste slag available for commercial use. Foamed slags have been developed that are satisfactory for use in concrete block and mass concrete construction. The principal methods now used are those that have been adapted from European practice, such as modifications of the Gelsenkirken machine. Even simple methods, such as spraying streams of water onto the slag as it is being poured from the ladle into a foaming pit, are successful. During the year a method called the foaming-bed process, which has been developed in England, was introduced into the United States. Essentially it consists of pouring slag from the ladle into a large concrete box in the bottom of which are a multitude of small water fountains. A demonstration unit was built and operated at the Monessen plant of the Pittsburgh Steel Co.

The lightweight-slag products now marketed in this country meet current specifications and are comparatively low-priced; consequently, sales have increased to over 1,000,000 tons annually. However, their average weights range from about 30 to over 50 lb per cu ft, much higher than the unit weight of expanded vermiculite or perlite. Consequently, foamed slag has not been widely applied in the lighter-weight uses.

Demand for aggregates of all types has been high during the past year; and, although requirements in the building industry appeared to be tapering off at the end of the year, the prospects for continued high aggregate demand appear to be good, particularly if the advocates of increased highway construction are successful in their promotion of an expanded program.

A source of concern to the owners of permanently-located aggregate plants is the steady increase in freight rates during the past few years. Producers report that truck hauls are increasing in length, and there are indications that the permanently-located plants are likely to have more difficulty competing with portable plants that are set up to work local materials. Some producers have expressed apprehension that this trend may reduce the quality of aggregates being used, as under these conditions there is always a temptation to utilize lower-quality local aggregates rather than pay a premium for standard-quality materials shipped from some distance.

Ice is reported to be of value in mass concrete construction to reduce the temperature. Finely ground ice was added instead of water to the mix and the precooling thus obtained is said to keep the heat development within safe limits during the critical curing period.

## asbestos

As in 1947, the world demand for asbestos was greater than the supply. Canadian production has been expanding, and at least one new mine of considerable promise is in an early development stage. The United Asbestos Corp. has reported the discovery of a substantial deposit of asbestos in Quebec, and a drilling program is proceeding to evaluate the extent of reserves more fully. The company has claimed the finding of more than 50 million tons of ore. Blue asbestos is being mined on a modest scale in Wittenoom gorge of the Hamersley range in a remote section of Western Australia. The asbestos seam is about 2 in. thick and is mined by a room-and-pillar method. The output, which is now small, is being increased. All of it is consumed in Australia. Bolivian blue asbestos is also receiving more than usual attention. It was reported that the Peak asbestos mine, situated near Belingwe in South Africa, was rapidly nearing the producion stage and that it had potentialities of becoming a major producer of chrysotile. The Croft mine, which was closed during the depression, was being reopened by the Mashaba Rhodesian Asbestos Co. Amosite production capacity in South Africa is being increased by 50 per cent. There have been reports of developments in France and French Morocco, but the commercial promise of these deposits is said to be questionable. The new capacity will be welcome, but it is unlikely to be adequate to satisfy requirements while demand remains at present levels.

Many varieties of asbestos have found commercial use, but anthophyllite generally has such a weak fiber that it has had little utility in the past. However, during the past year this fiber appears to be finding its niche in the industrial structure, particularly in plastic insulation. The product is now in commercial production, and the prospect of developing a substantial market is considered promising.

Under current shortage conditions, a great deal of work is being done by industrial firms on subsitution of other fibers, adaptation of short fibers to uses that ordinarily require longer grades, and even on research looking toward complete synthesis of asbestos. Some success has been reported in the adaptation of shorts to longer uses, but there is little indication of any startling research advances on substitutions or synthesis during the past year.

The magnetic iron oxide content of Canadian chrysotile makes it less satisfactory for electrical insulation than is low-iron Rhodesian. Magnetite is hard to remove, but a new process developed by Johns-Manville is said to have been successful. The product is a thin asbestos paper. Other experiments looking toward solution of the magnetite problem are being carried out by at least one other firm also.

The physical properties and general technology that govern the utility of asbestos fibers are not widely known. A useful paper describing the properties of asbestos and research methods, written by M. S. Badolet, was published in the *Canadian Mining and Metallurgical Bulletin.*

## carbon dioxide and cement

During the past couple of years scientists and the public have been much interested in the use of carbon dioxide in controlling weather, and many experimental exploits have been reported. On the other hand, during the year the Air Force indicated that its experiments had not proved successful enough to encourage further large-scale experimentation on weather control. Further experiments, however, will be carried out on a modest scale by the several agencies engaged in this work. It appears that the present techniques are effective only under special conditions wherein precipitation can be easily induced.

During 1948, demand for cement has been so great that the industry appears to be approaching its "practical" capacity. A new record of about 205,000,000 barrels was attained. From time to time, spot shortages were reported. Many expansion programs were in progress.

The year was equally notable in its legal aspects. After extended litigation, the Supreme Court finally upheld the Federal Trade Commission "cease and desist" order which prohibits the multiple-basing point system of pricing used by the cement industry. As the decision has extremely wide application throughout industry, because it establishes precedent for other commodities as well as cement, it became one of the most publicized legal decisions in history.

Conceivably, the decision could have a strong effect on the competitive position of individual plants that have been built and developed on the assumption of the past marketing structure. However, many uncertainties remain in the situation. Some firms took the stand that they are legally bound to sell on an f.o.b. plant basis only and that absorption of freight is no longer allowable. Other interpretations are more liberal —in other words, that freight absorption will be legitimate if there is no intercompany collusion in their application. A senatorial committee to investigate the situation began to hold hearings toward the end of the year, and it appears that full clarification of the future pricing rules will not be obtained until the legislative program is settled and the enforcement policy of the Federal Trade Commission has been established.

A method of improving the sanitation of concrete floors has been reported. It is claimed that a relatively germ-free concrete floor can be produced by adding about 1 per cent pentachlorophenol to the cement.

## clay

The heavy-clay products industry is enjoying its first real boom since the 1920's. After the war, plants were rehabilitated, modernized, and considerable new construction has taken place. The expansion program has been so successful that during the year production attained a rate that equalled demand, and the commodity was in easy supply.

The structural-clay products industry has not had the benefit of large-scale research programs to the degree that producers of many other commodities have. However, under present more prosperous conditions research programs are receiving more attention. A study by Arthur D. Little, Inc., resulted in a proposal that a long-term research program costing a minimum of $1,250,000 in the next five years be conducted by the industry. The proposal was adopted by the Structural Clay Products Institute, and the project is making progress.

## diamonds

Gem diamonds retained their high degree of popularity in social circles and dollarwise. This use dominated the market, but in 1948 industrial diamonds had greater fundamental importance. Efforts are being made by many countries to increase their purchases of industrial diamonds, both for current use and for stock piling. Serious efforts were being made to expand African output. Expansion of production of industrials is relatively difficult owing to the remote locations of the principal mines and the conditions under which they are worked. Noteworthy in the South American branch of the industry has been the increased production in Venezuela and some decline for Brazil. The reasons for this are not completely clear, but it is rumored that movement of diamond miners from the Brazilian to Venezuelan rivers has been a primary cause. It has been reported

**Quarrying** Eagle-Picher celatom is a relatively simple operation.

that some North American capital was employed in large-scale systematic examination of diamondiferous alluvials in Venezuela.

A substantial quantity of industrial diamonds was purchased by the Economic Co-operation Administration for stock piling. Payment for these diamonds was made out of a sterling fund that has been accumulated by ECA in the operation of the European recovery program.

Loose diamonds and tools and devices incorporating diamonds were added to the positive list of commodities requiring licenses for export by the Office of International Trade of the Commerce Department.

A method of drilling fine holes through diamonds for making wire-drawing dies has been described. In drilling, a current is fed through the needle, and a minute arc formed at the contact with the diamond greatly speeds the drilling process.

Although diamonds have a reputation for being highly controlled, extralegal operations are also noteworthy in the industry. During the past year it was reported that considerable quantities of Tanganyika diamonds were being smuggled. It was reported that shipments of cut diamonds to the United States from Palestine were declining.

## feldspar

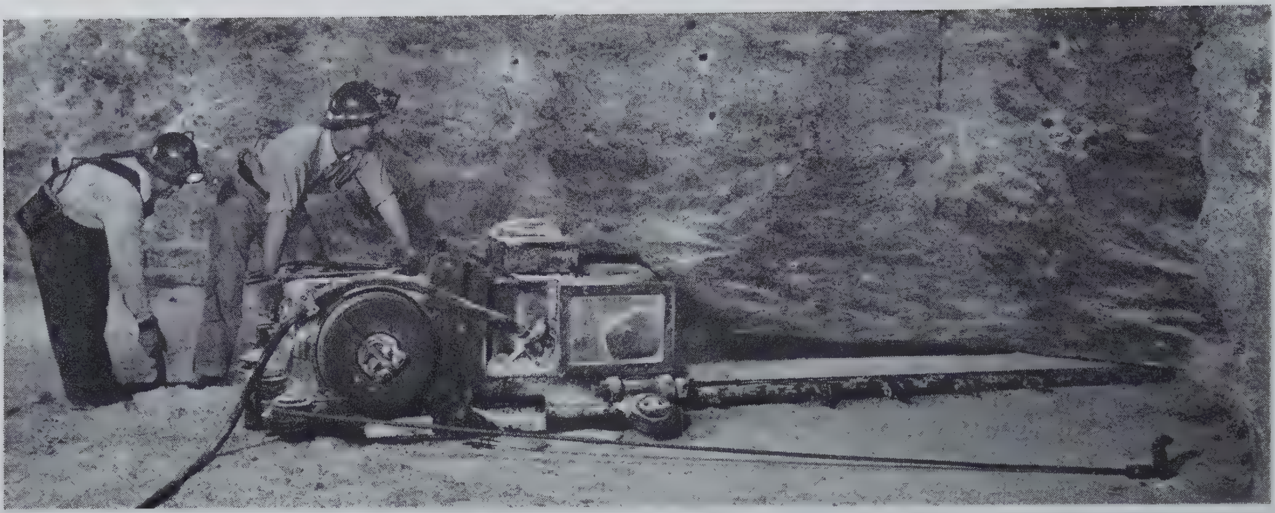
Substantial quantities of nepheline syenite are imported into the United States from Canada, but domestic nepheline syenite has never found a substantial market in the ceramic industry owing principally to its high-iron content. However. considerable work has been done on the material recently, particularly as it has been made available as a by-product, and it is reported that iron content can be reduced from 4.6 per cent in natural rock to 0.85 per cent after beneficiation.

The feldspar flotation plant of Consolidated Feldspar Corp., at Parkdale, Colo., was put into operation during the past year. A flotation mill was also erected by Golding Keene Co. near Gilsum, N. H., and was in production during the latter part of the year. Also scheduled for operation in the early part of 1948 was the new grinding mill of the Appalachian Minerals Co. at Monticello, Jasper County, Ga.

## fluorspar and graphite

Consumption of fluorspar in the United States is estimated at having been the second highest in history in 1948. Production was started near Delta, Utah, by several operators. The trend toward use of the heavy-media separation process continued. Such a plant is projected by the Crystal Fluorspar Co. in Illinois.

As is usual in peacetime, the domestic graphite industry has declined since the war. Domestic graphite is not held in high regard by consumers. They prefer Madagascar flake, as it will make a durable crucible and usually can be obtained in adequate quantities and uniform quality. During the past year, however, graphite production has been low in Madagascar as a result of a rebellion, and there has been a shortage both for current use and stock piling. Producers in Madagascar are being assisted in their efforts to rehabilitate and expand their mining operations so that they can adequately supply the market. Although the prospects appear to be good that the efforts to stimulate output on Madagascar will be successful, the element of uncertainty has revived interest in domestic material. There are indications that domestic graphite may be of greater utility than generally has been believed. To assist in the evaluation of all types of graphite for crucible use, the Bureau of Standards has established a project aimed at developing a set of specifications that can be uni-



**Short wall mining machine** in operation in a New Mexican potash mine.

versally applied. This project is expected to require several years for completion but may provide some information that will be useful in guiding the procurement policy of both the Government and the consuming firms at a relatively early date.

### lime and lithium

As is well-known, limestone occurs in virtually every state in the Union, but it is interesting to note that firms are not always able to find easily the type of deposit desired for a particular use. Some firms have found it necessary to put on extensive exploration programs to find the proper deposit. As specifications of lime become more exacting, the need for high-specification stone increases. Producers are advocating percentage depletion allowances as a means of assisting them in meeting their reserve problems.

The use of slag as an agricultural liming material has been promoted both in Europe and in the United States for many years, with only limited success. However, interest has grown considerably in this country within the last few years. The National Slag Association is conducting research programs at several universities. Slag has definite liming value and is also said to provide many of the minor fertilizing elements, such as iron, sulphur, boron, and magnesium, that are deficient in many soils. Sales now total somewhat less than 100,000 tons annually.

There are, from time to time, rumors of various uses of lithium compounds that promise to increase substantially the demand for these commodities, but up to the present time the industry is still operating at a comparatively low level, as compared with wartime.

### magnesia, mica, and mineral wool

The use of magnesium compounds, particularly the refractory magnesias, has been growing since the end of the war. All the various sources, including seawater, brucite, magnesite, and dolomite, continue to serve portions of this market. Demand has been high, and some interest has been shown by domestic consumers in foreign magnesite, including the well-known source in Austria and the substantial deposits that occur in Brazil. Spot shortages of refractory magnesia occurred during the year.

Domestic production of high-grade sheet mica was not large in 1948. India has been in a disturbed state and Brazilian mica has been serving a larger portion of the American market. Ample quantities of sheet mica were available both for current consumption and stock piling. Output of ground mica, which can be produced by mechanical methods, in the United States was large. Further progress was made during the year in the program that looks toward the synthesis of fluorine-phlogopite mica. Staffs have been built up by the Bureau of Mines and other organizations, equipment acquired, and some experimental progress made.

A combination of a boom in building and general public acceptance of the advantages of heat insulation greatly expanded the market for mineral wool after the war. The industry rapidly increased its production capacity, and by 1948 this expansion program had caught up with demand and the commodity became readily available.

Consumers of asbestos have had such difficulty in obtaining supplies and are so pessimistic regarding the prospect of adequately expanding asbestos-mining capacity that they are intensifying their efforts to adapt glass wool to their use. Such efforts have not been outstandingly successful in the past, but the present one may be worth watching. Several manufacturers have found their expansion programs blocked by lack of asbestos, so the incentive for successful research is greater than ever. One such substitution is a glass fiber-resin combination for use as electric cable insulation.

### nitrogen, monazite, and phosphate rock

An outstanding development of the fertilizer industry has been the recent growth in direct application of anhydrous ammonia to soils. The method was developed in the deep South owing to the shortage of solid-fertilizer nitrogen and the availability of anhydrous ammonia, for which there have been no conversion facilities. The ammonia is transported to the field under high pressure in liquid form and released directly into the soil through a set of heavy knives mounted on a tractor, which are pulled through the earth at a depth of about six in. High efficiency and low cost are claimed for the method. During 1948 the general shortage of nitrogen continued, and the commodity was under international allocation.

The supply of monazite during the past year has improved somewhat. Some has been received from Brazil. There has been no practical improvement in the prospect of obtaining material from India. Production of monazite was started by Rare Metals Co. at McCall, Idaho, from placer sands. This is the first domestic commercial production of this mineral since World War I. Interest in monazite as a commercial source of atomic energy is not as high as it was a couple of years ago. It does have atomic potentialities, but its development is still in the research stage.

Since the end of the war, there has been a tremendous increase in the production capacity of phosphate rock in the United States, and a new production record, estimated at over 9,500,000 tons, was established in 1948. The major developments have taken place in the East, but the western phosphate districts have also become active. A substantial portion of the production in the western area is being exported under military occupation programs to the Orient. Domestic demand in the West is growing and efforts are being made to broaden and increase this market. The assumption is that if low-cost power becomes available it will be possible to produce high-analysis phosphates that can be shipped for long distances economically. At the end of the year, the $4,000,000 phosphorus plant that is being built near Pocatello, Idaho, by the Westvaco Chemical Corp. was nearing completion. Operation was expected to start in April 1949.

International Minerals & Chemical Corp. began production at its new phosphate-rock mine near Bartow, Fla., in 1948. This mine is said to have a production capacity of about 1,500,000 tons of phosphate annually and is the largest phosphate mine in the Western Hemisphere.

## potash and quartz crystals

Demand for potash again exceeded the supply in 1948; consequently, domestic producers continued their expansion programs. Most of the potash produced in the United States is mined by conventional methods, but some interest has developed in a solution method. During 1948 experimental operation with the Cross solution mining process was continued in the Carlsbad, N. Mex., district. Resumption of substantial imports, as was common before the war, has been expected by domestic consumers, but conditions in Europe have not yet been such as to encourage this trade. Imports of European potash during the past year have been only minor in size, and the United States was a net exporter. The deposit of potash that has been discovered in Saskatchewan, Canada, is quite deeply buried, and therefore the prospect of early development is not strong. The potash-bearing strata dip as they approach the border, and the prospect of discovering material of commercial value at reasonable depths on the American side of the border is now considered rather doubtful.

It has been reported that a substantial potash deposit in Landes Dept., France, has been discovered and developed to the production stage.

In 1948 the demand for quartz crystal was only a fraction of that during the war. Many offerings made by Brazilian producers failed to find buyers, even at greatly reduced prices. However, the commodity has not lost its fundamental importance, and a great deal of attention was directed toward means of obtaining a domestic supply of piezoelectric material. A comprehensive project is being conducted by the Squier Signal Laboratory through which the efforts of commercial, university, and government laboratories are being co-ordinated. A great variety of materials is being investigated in addition to quartz. Crystals of ethylene diamine tartrate, which are now being produced and used in substantial quantity, have proved satisfactory for telephone circuits. There is even some promise of the possibility of developing electrical control methods that would not require piezoelectric crystal materials at all. This might be accomplished through a magneto-striction method.

To date, however, the general consensus is that the most promising line of investigation is that of synthetic quartz where rugged physical properties are required. In the past few months announcements by investigators have claimed real success in the synthesis of quartz crystals.

A unique use of quartz crystal is said to have been found by the medical profession in gallstone operations. A quartz crystal on the end of a probe helps the surgeon find and remove all the stones.

## refractories

The trend toward the use of higher temperatures in furnaces to increase output has increased the need for refractories that will perform satisfactorily at temperatures over 3000F. These high-grade refractories also are found to have great durability under the unusually corrosive conditions found in many chemical and metallurgical processes. Conventional silica brick, containing about 1.2 per cent alumina, alkalies, and titania, gives reasonably good service in open-hearth roofs, but superduty silica brick, which contains not more than 0.5 per cent of these impurities, improves service life 20 to 25 per cent. It also has lower permeability to gases and allows higher-temperature operation of the furnace. Special high-purity mortars have been developed for use with the superduty silica brick. Advantageous properties are also being obtained by improving the high-alumina refractories. The properties improve approximately in direct ratio to the alumina content. The 50, 60, and 70 per cent types, usually made with diaspore clay, are well known. As the supply of diaspore declines, brick manufacturers are turning to the more costly raw materials, bauxite and fired alumina, to maintain quality. High-alumina refractories of the 80, 90, and 99 per cent types are receiving increasing attention. The latter is said to have a fusion point of 3722F, whereas that of fifty per cent brick is about 3225F. Both the 90 and the 99 per cent alumina refractories are in relatively early development stages.

Specifications of kyanite to be purchased by the Munitions Board stock pile have been modified to include fine-grained as well as lump kyanite of refractory quality. Historically, our supplies of high-grade refractory kyanite have come from India; but owing to transportation problems and difficulties arising from the change in that country's status, shipments to the United States have been far from adequate during the past couple of years. Consequently, consumers have welcomed the development of an alternative source of supply in Kenya. The Kenya kyanite has been fully tested and found to be a satisfactory substitute for Indian.

The Federal Trade Commission issued a "cease and desist" order against the American Refractories Institute and a number of companies in the industries. The industry was ordered to refrain from certain specified price practices that were considered to be for the purpose of enhancing, unifying, or maintaining prices.

### salt and sodium compounds

Production of salt during the past year continued to increase, and a new record of slightly over 16,000,000 tons was attained. The salt industry figured prominently in the legal history of the year, as it was on the so-called "Morton Salt case" that the Supreme Court placed restrictions on the quantity discounts that have been general in the industry.

Iodized salt has been a staple in both human and animal diets for a comparatively long time. In fact, the practice is so widely accepted that efforts are being made to pass a law that would make the use of iodine in table salt mandatory. However, much remains to be learned about the effect of iodine in the diet. To throw more light on this problem, the Salt Producers Association has established research projects at several schools to study the effect of iodized salt on animals.

The Westvaco Chlorine Products Co. began to produce trona from a mine near Green River, Wyo. This is the first mine of its type in the United States. The product, trona, is being used in its crude state, but the Company has indicated that it intends ultimately to process the material into soda ash. Toward the end of 1948 the general shortage of soda ash in the domestic market was reduced, and it was anticipated that the material would be in easy supply sometime in the early part of 1949.

### stone and sulphur

This has been another record-breaking year for the stone industry. Demand for broken stone has been high owing to the building boom and growth in the highway program. The increasing construction of monumental buildings has also benefited the dimension-stone industry.

According to D. W. Kessler, better methods of selecting marble for durability are needed. Studies by the National Bureau of Standards indicate that not only do marbles erode through the effect of acid leaching but, over a period of years, may be subject to destruction through sugaring — which seems to be due to thermal expansion of the calcite crystals. Permanent increase in volume of as much as 3½ per cent has been reported. When sugaring advances to the point that the bond between crystals is broken, crumbling results. Efforts are being made to determine if the laboratory findings can be correlated with observations on the same materials under exposure to weather.

The market for split-slate shingles during the past year has been exceptionally good as this high-grade product is used in constructing more expensive homes.

The rate of production of sulphur has become so great that estimates of the life of reserves must be revised downward substantially. In 1948 production totaled approximately 4,900,000 tons—a new record. Not only do the domestic producers of native sulphur provide for the extremely high requirements of domestic consumers, but since the war the entire world has been clamoring for such large tonnages that the industry has been forced to operate at capacity and draw on stocks. Exploration and expansion programs are general throughout the industry. The Texas Gulf Sulphur Co. began production in June at its new plant on the Moss Bluff Dome.

### other items

Maritime Barytes, Ltd., is reported to have begun drilling a substantial deposit of barite ore in Nova Scotia. Tariff on imports of barite into the U.S. was reduced from $4 to $3.50 per ton.

Production of an expanded type of bentonite has been reported as being suitable for taking up large quantities of oil and as an absorbent for vapors, catalysts, and dyes. Bentonite is swelled in water, after which the mixture is frozen. The frozen material is then broken to give a large surface, after which it is exposed to cold, dry air and subjected to high vacuum until all the moisture is removed.

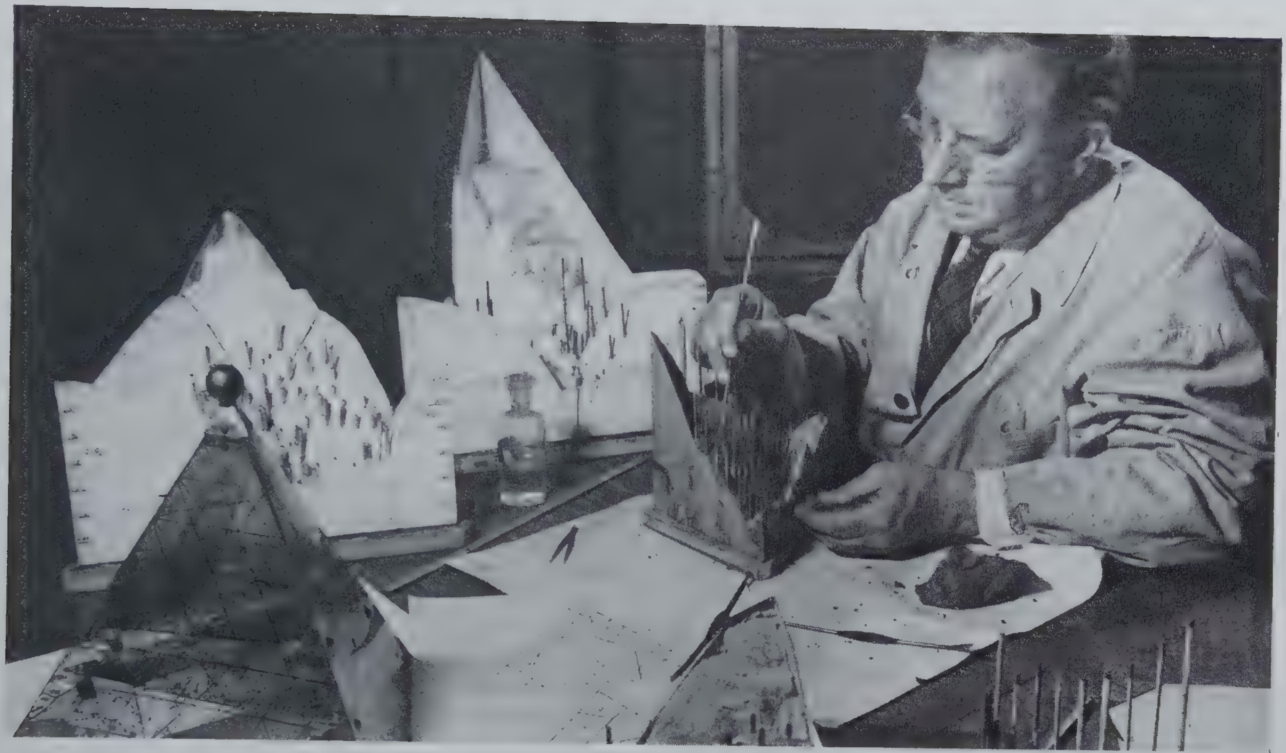
Exploration in Nova Scotia has indicated the presence of extensive deposits of diatomite which, if found to have the qualities and physical properties, might have a market in Eastern United States.

The Eagle-Picher Co. completed its plant and began the production of diatomaceous earth at Clark, Nev.

Improvement in the techniques of making and processing synthetic sapphire for bearing uses were reported in 1948. Gem grades of synthetic sapphire are improving also. It is said to be possible now to produce star sapphire.

## Crystallographic Society Plans Meeting

The fourth Annual Spring Meeting of the Crystallographic Society of America will be held at the University of Michigan, Ann Arbor, April 7 to 9, 1949. Rooms and meals will be available at the Michigan Union which will handle reservations. The closing date for titles of papers to be presented at this meeting was Jan. 15 and for abstracts March 1; they should be sent to Howard T. Evans, Jr., Laboratory for Insulation Research, MIT, Cambridge 39, Mass.



**Careful refining of ferroalloys** requires a knowledge of slag melting points. These ternary and quaternary diagrams give the melting points of the various slags involved.

# FERROALLOY METALS . . .

## . . . *mark one of the best years with impressive rates of commodity production*

By R. G. KNICKERBOCKER • COMMITTEE ON REDUCTION OF FERROALLOY ORES, AIME

WITH a 1948 metal-commodity production valued at $71 billion, it is easy to understand how we are not only short of some of our important ferroalloy metals for present industrial use, but also why we do not have adequate emergency stock piles of the majority of these strategic items.

The confusion and uncertainty during 1942, when we were suddenly confronted with the fact that we had to rely on domestic sources for all of our manganese and chromium, again looms as a possibility as we realize that over 40 per cent of our metallurgical-grade chromite and more than 33 per cent of our manganese supply came from Russia in 1948. With reference to manganese, we concur with the opinion of one of our most capable and progressive industrial steel metallurgists who recently stated: "We need a method that will handle low-grade manganese ore on a scale that could provide at least 500,000 tons of contained manganese per year. We need the pilot-plant work behind us in 1949 for we may need the full-scale operation before 1951."

We believe that the relatively small amount of research and development work on the production of ferroalloy metals from low-grade, domestic resources at this time indicates that we are again leaving the major portion of this process-development work to a future period of wartime emergency instead of doing it in peacetime when there is comparatively easy access to scientific man power, materials, and time.

Special attention is being given to the procurement of strategic metals for stock piling. Two teams of investigators have been sent to India and the Union of South Africa—the two foreign manganese sources which seem to offer most promise.

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## titanium

Dominion Manganese, Ltd., Toronto, has recently announced pilot-plant operations for the production of titanium metal. This new process entails the direct reduction of the oxide to the metal. They estimate the cost of their metal, in the future, to be $1.50 per lb of titanium. One of the values of higher purity titanium is that it can replace or exceed the valuable strategic properties of some of our domestically scarce ferroalloy metals.

Progress is reported on the development of a rutile-matte smelting procedure in the laboratory for the preparation of titanium chloride and pigment oxide from the Arkansas rutile deposits at the Bureau of Mines laboratories at Rolla. The Kroll-Bureau method produces ductile titanium metal from titanium chloride. Announcement of the completed plans for the construction of a titanium smelter at Sorel, Que., to treat the titanium iron ore from Allard Lake, Que., was of importance this year.

Considerable research work in the Bureau of Mines laboratories at Bauxite, Ark., has resulted in successfully extracting ilmenite from the bauxites being treated in the modified Bayer process in the Hurricane Creek plant of the Reynolds Metals Co. at Bauxite.

Increased importance of the properties of titanium nitride and the direct effect on the properties of steel treated with titanium are made evident by the amount of fundamental research work being conducted on the relative effectiveness of titanium and aluminum for stabilizing nitrogen or removing it from solution in the iron. The importance of the Bureau of Mines fundamental studies by K. K. Kelley of the Berkeley, Calif., station, is well recognized in this and other phases of metallurgical research work on ferroalloy metals.

The Tata Iron and Steel Co., of India, is producing ferrotitanium. A preliminary low-temperature reducing sinter is made at 1100C and the smelting operations are carried out in a basic-lined shaft furnace at 1600C. The basic slag is treated to recover titanium either by silicon or aluminum reduction.

The consumption of ilmenite, the principal source of titanium oxide, has established a new annual peak for the sixth successive year. Residues from phosphate washers and from alumina plants are being investigated. Major consumers of ilmenite are sponsoring extensive exploration for new deposits. Approximately 40 per cent of our ilmenite concentrate is imported.

## nickel

The War Assets Administration offered the Nicaro nickel plant in Cuba for disposal. The government agency desires to dispose of the plant on a basis that will allow resumption of nickel-oxide production for use by the steel industry in case of a military emergency.

Nickel imports in 1948, for the first nine months, are estimated to exceed 1947 imports for the same period by approximately 19 per cent.

International Nickel Co. reports Canadian nickel deliveries, in 1948, at a record peacetime high. Electric-power shortages in this area are a bottleneck. Ingot output of chromium-nickel stainless steel is estimated to be 15 per cent above 1947. The house-building industry, heat resisting alloys, the aircraft industry, and the hydraulic equipment manufacturers were a few of the industrial consumption organizations.

A new nickel field, discovered in 1948 in Canada, is reported by the Saskatchewan Government geologists in the area immediately northwest of Amisk Lake within 15 miles of the railhead at Flin Flon.

## cobalt

The Howe Sound Co. has continued their development and research at Forney, Idaho, on the cobalt-copper-gold ore resources in Lemhi County, 125 miles northeast of Boise. They expect to be in production of cobalt metal and oxide late in 1950. This new domestic development in the production of copper and cobalt was assisted by the Boulder City and Salt Lake laboratories of the Bureau of Mines.

Atomic energy officials reported this year the development of radioactive cobalt for the treatment of cancer. This work is to be continued for two or three years. The cost of cobalt is estimated to be one tenth of radium costs.

The Bethlehem Steel Co., which recovers cobalt as a by-product at the Cornwall iron-ore mine in Pennsylvania, was again the only producer of commercial cobalt from domestic resources. Consumption of cobalt was 12 per cent greater in the first three quarters of 1948 than for the same period in 1947. Suppliers' stocks declined 62 per cent. The Belgian Congo showed a production of 2000 tons per year of cobalt.

## ferrochromium, tantalum and columbium, and molybdenum

Ferrochromium consumption during the first nine months of 1948 was approximately 9.5 per cent greater than for the corresponding period of 1947.

General electrochemical factors and conditions for obtaining adherent ductile nonporous coatings of tantalum and columbium by hydrogen reduction of their pentachlorides have been investigated recently.

The 1948 domestic production of molybdenum comes from six states: Utah, with the highest production, followed in order by Colorado, New Mexico, California, Arizona, and Nevada.

For the first three quarters of 1948 a gain of 22 per cent in the consumption of molybdenum concentrates was made over the corresponding period of 1947.

## progress in steel making

Recent investigations resulted in progress in the replacement of nitrogen for nickel in austenitic steels. In this country nitrogen has been added to the high-chromium ferritic steels but little attention has been paid to the addition of nitrogen to austenitic steels. This work is intended for the conservation of nickel and possible improvement of the alloy. One of the prerequisites was the necessity of obtaining ferroalloys which contained appreciable amounts of nitrogen.

Research has continued on high-temperature corrosion of stainless steels of interest to the designers of gas turbines, coal and oil-shale alloy retorts, and other high temperature equipment. Chromium content is reported to be the greatest factor in controlling resistance to oxidization and high-temperature flue gas atmospheres.

The production of chromite from Turkish mines has shown a steady increase during the last two years due principally to the revaluation of Turkish currency during 1946.

The use of oxygen in the production of stainless steel has been one of the factors responsible for the present larger tonnage. Advantages gained in the use of oxygen for the manufacture of stainless steel are: (1) high percentage of stainless steel scrap can be used; (2) high percentage of chromium is recovered from the scrap; (3) the oxygen-chromium reaction is exothermic; (4) control of chromium content is improved; and (5) quality of the production in the straight chromium grade is improved.

### manganese and tungsten

An improvement to the manganese-matteé smelting procedure by Helge Lofquist was disclosed in 1948. High-grade ferromanganese is produced from low-grade manganese ores or manganiferous iron ore by first preparing a low-grade molten spiegeleisen and blowing a mixture of pyrites and reducing agent into this bath in a Bessemer converter with a controlled amount of air to give a low melting oxide-sulphide manganese slag which in turn is reduced to high-grade ferromanganese. It is claimed that the Bessemer operation is exothermic and can be performed without the use of additional fuel.

The Salt Lake City station of the Bureau of Mines reported the results of investigations on sulphur dioxide leaching of eighty samples from 58 separate deposits of low-grade domestic oxide-manganese ores. Work has been continued at this experiment station in mining exploration of the vanadium-bearing phosphate shales of Wyoming and Idaho.

Additional studies on health hazards from manganese poisoning during the melting of Hadfield steel in electric furnaces were conducted during 1948. It is reported that ventilation at the rate of 40 to 50,000 cubic meters per hour removed all obnoxious gases and over 98 per cent of the manganese from the air. The dust gathered from under the umbrella of the furnace is reported to contain 26 per cent manganese.

The results of investigations at the Boulder City, Nev., Bureau of Mines experiment station were reported on the electrowinning of manganese from chloride electrolytes.

The U. S. Steel Corp. is interested in studying the possibilities of obtaining supplies of manganese ore from Brazil. The government of India is planning on an export tax of twenty rupees per ton of manganese ore. This would amount to $6.06 per ton at current rate of exchange and could increase the price of ferromanganese approximately $15 a ton. It is estimated that ferromanganese production established a new record during 1948, being 15.5 per cent greater than in 1947 and 1.0 per cent greater than the previous record year of 1944.

The Electro Manganese Corp., Knoxville, Tenn., reports an all-time record in 1948 production of electrolytic manganese. Also, in spite of higher wages, ore costs, materials, and supplies, the price of electrolytic manganese, effective Jan. 1, 1949, has been reduced to $1.28 per pound—carload quantities delivered, packed in the Eastern Zone.

During 1948, North Carolina became the second largest producer of tungsten in the United States. The Hamme district has been developed since 1943. The average quarterly consumption of tungsten ore and concentrates in short tons of sixty per cent $WO_3$ for the first three quarters of 1948 was 5.1 per cent greater than for the corresponding period of 1947.

### degassing ferroalloys

Important developments in vacuum technique have led to investigations intended to produce suitable commercial methods for degassing ferroalloys. Mond nickel, electrolytic nickel, cobalt, chromium, ferrochromium, manganese, ferrosilicon, ferrotungsten, ferromolybdenum, aluminum, ferrovanadium, ferrotitanium, and ferrocolumbium were vacuum treated at 1110 to 2550F. A substantial removal of hydrogen was obtained with all except aluminum and ferrovanadium. Cobalt evolved a particularly large amount of carbon monoxide and dioxide. The removal of nitrogen from ferrosilicon and ferromolybdenum was incomplete. Ferrovanadium, ferrotitanium, aluminum, and ferrocolumbium released practically no nitrogen. An additional interesting possibility is the production of low-nitrogen, low-carbon ferrochromium, since the carbon content of ferrochromium was lowered during the vacuum treatment and this was judged to be caused by a reaction of the oxygen present in the ferroalloy.

Estimates of power requirements by 1960 in the Pacific Northwest have been stated to be twice the present consumption.

The Keokuk Electrometals Co. of Keokuk, Iowa, have purchased the war-constructed electroalloy plant at Rock Island, Wash., on the Columbia River and announced intention to begin operations.

The Electrometallurgical Co., a unit of Union Carbide and Carbon Corp., has announced plans for the erection of a new ferroalloy plant near Marietta, Ohio.

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## ARMY OFFERS RESERVE COMMISSIONS

The U. S. Army's Scientific Manpower Section announces that Uncle Sam is offering reserve commissions, ranging from First Lieutenant up to, and including, Colonel, to qualified mining engineers. Requirements include citizenship, a bachelor's degree in mining engineering or a related technological field, and encompass 21 to 55-year age limits. Progressive experience in discovery and exploration, development, production, or beneficiation is required, but such experience may fall within the framework of college teaching, technical writing, technical sales and service, as well as exploration and actual production.

The reserve commissions will be made for the Corps of Engineers, Military Intelligence, and the Quartermaster Corps reserves. Determination of the grade for which applicants will be commissioned will hinge mainly on education and experience, including, of course, the approval of an examining board and final approval from the Adjutant General. The explanatory Army Circular 210, dated July 14, 1948, is available from The Adjutant General, Dept. of the Army, Washington 25, D. C.

ANNUAL REVIEW

# Physical Metallurgists . . .

## . . . active in research—deformation, grain growth, transformation, semiconductors studied

By **R. L. FULLMAN** and **D. TURNBULL** • RESEARCH ASSOCIATES, GENERAL ELECTRIC CO.

During the past year there have been a number of significant investigations that have furnished evidence on the driving forces governing grain growth and on the role played by boundary impurities.

Thus Burke has shown that in high-purity alpha brass the rate of grain growth in the earliest stages is approximately inversely proportional to the existing grain size. This relation agrees with one derived by Zener assuming that surface energy was the driving force in grain growth. Also in confirmation of the surface energy hypothesis, Burke found that growth virtually stopped when the grain boundaries or even only the grain corners were melted.

Further evidence in favor of the surface-energy driving-force hypothesis was furnished by the experiments of Beck, Holzworth, and Hu which indicated that in high-purity aluminum the rate of grain growth at a given temperature is a function of grain size alone and independent of the past history of the specimen.

Beck, Holzworth, and Sperry have studied the effect of the second phase on the rate of grain growth in aluminum-manganese (0 to 1.1% Mn) alloys. Below the solution temperature, grain growth is almost completely inhibited, while above this temperature it proceeds at a normal rate until the thickness of the specimen is approached. Close to the solution temperature, the kinetics of the process are quite analogous to the kinetics of primary recrystallization in specimens that have been strained a small amount. There is a long incubation period and the final grain size is many times larger than the specimen thickness. They suggest that the latter phenomenon be designated "discontinuous grain growth."

Burke has found that the rate of grain growth is much greater in high-purity brass than in commercial brass, which may indicate that boundary impurities are holding up grain growth in the latter. For high-purity brass the activation energy for grain growth was 40,000 cal per gm atom, a number of the same order as for the interdiffusion in alpha brass.

Bowles and Boas, as a result of their experimental work, propose that the kinetics of secondary recrystallization is controlled by the texture rather than the prior deformation directly.

Further observations have been made on the phenomenon of "polygonization." Cahn has reported on this for zinc crystals of high purity. After deformation and heating slightly below the melting temperature, the strip broke up into small lamellar crystallites having orientations about ⅛ to ½ a degree apart and approximating the orientation of corresponding regions in the deformed strip. Guinier and Tennevin have reported a similar phenomenon in high-purity aluminum.

Honeycombe and Boas have studied the recrystallization of alpha-beta brass. They found that the least deformed of the two phases, beta, might recrystallize at a lower or higher temperature than alpha, depending upon the heat-treatment prior to deformation. They have also shown from resistivity measurements that, when embedded in the alpha phase, the beta phase may be disordered at room temperature by severe cold working.

### • transformations

Quite a number of contributions have been made concerning the nature of the martensite transformation, perhaps the least understood of all solid-state reactions.

Two sets of investigations have shown that certain transformations in pure metals exhibit the most important features of the martensite reaction, i.e., transformation only during cooling, and stabilization. Barrett and Trautz have observed such a transformation in lithium at low temperatures. Partial transformation to a close-packed structure, accompanied by audible clicks, was found to take place below dry-ice temperature. Low-temperature cold work caused additional transformation. Troiano and Tokich found the transformation of cobalt to occur during cooling, with the characteristics of a martensite transformation.

Generally the martensite reaction has been thought of as a shear-type transformation not involving a nucleation process. However, Fisher, Hollomon, and Turnbull have advanced the concept that martensite-type reactions are nucleated by embryos of the segregating phase retained in quenching from a high temperature. These embryos are promoted to nuclei ("athermal" nucleation) upon cooling, since the critical size of a nucleus decreases with decreasing temperature. Stabilization takes place because the concentration of subcritical embryos tends to decrease upon holding at a temperature far below the transformation temperature. They also suggested that martensite grows by rapid atom-by-atom diffusion across a coherent interface rather than by a semimacroscopic shear mechanism.

Kurdjumov has also made the suggestion that martensite forms by nucleation and growth, although he appears to believe that the nucleation takes place isothermally ("thermal" nucleation). Rather striking support for his growth mechanism has been obtained by Kurdjumov and Maksimova. They report that direct quenching of 6% Mn, 0.6% C steel in liquid nitrogen at —194C retains 100% austenite. More important, upon warming to —159C or above, a fraction of the austenite transforms *isothermally* to martensite (transformation continues for more than three hours at —159C). The limiting fraction transformed decreases with increasing temperature, falling to zero at $M_S$. The duration of the isothermal transformation period also decreases as the temperature rises. Similar effects were found for a 1.6% carbon steel. Although 20% martensite was formed during cooling to —194C, the 1.6% carbon steel continued to transform slowly at this temperature, and transformed more rapidly upon heating.

As pointed out by Kurdjumov and Maksimova, their data clearly suggest that martensite grows by a temperature-dependent mechanism having a small activation energy. The experimental value of the activation energy was 1600 cal per g atom. The importance of these observations to the theory of martensite formation and to the science of heat treating cannot be overemphasized.

Harris and Cohen have discovered a critical temperature, $\sigma_S$, above which stabilization of austenite does not occur. Depending upon the alloy content of the steel, $\sigma_S$ may be above or below the martensite start temperature, $M_S$. They also found that $M_S$ is dependent upon the austenitizing temperature and that this effect could not be accounted for by incomplete solution of carbides or by changing grain size.

Cohen has advanced a comprehensive theory of the martensite transformation, which accounts qualitatively for a great many of its characteristics, including stabilization and the existence of a $\sigma_S$. He adopts the concept of athermal nucleation but assumes that martensite grows by an elastic-shear wave that cannot be suppressed by lowering the temperature.

Other work has related to isothermal transformations. Nucleation and growth data have been obtained by Mehl and Dube for the formation of proeutectoid ferrite from austenite. They found the rate of nucleation to increase, then decrease, as the temperature of isothermal transformation was lowered. The growth rate of proeutectoid ferrite was observed to be more rapid along grain boundaries, where most proeutectoid ferrite was nucleated, than into grains. They also report that the rate of nucleation accelerates with time.

In their well-known treatments of the thermal nucleation problem Volmer, Becker, and their co-workers assumed either an equilibrium or steady-state distribution of embryos and nuclei. Inherent in their theory, as pointed out by Zeldovich in 1943, is the concept of a transient in the nucleation rate, when a steady-state distribution of embryos does not exist in systems with sufficiently slow diffusion rates. This was demonstrated independently by Turnbull. On this basis he was also able to explain satisfactorily the acceleration of nucleation rates with time observed by Mehl and his co-workers in several isothermal transformations.

Assuming the nearest neighbor hypothesis, Hobstetter has re-examined the problem of nucleation in precipitation from a two-component solution along the lines originated by Borelius. However, his treatment affords a less arbitrary interpretation of the size of the nucleus.

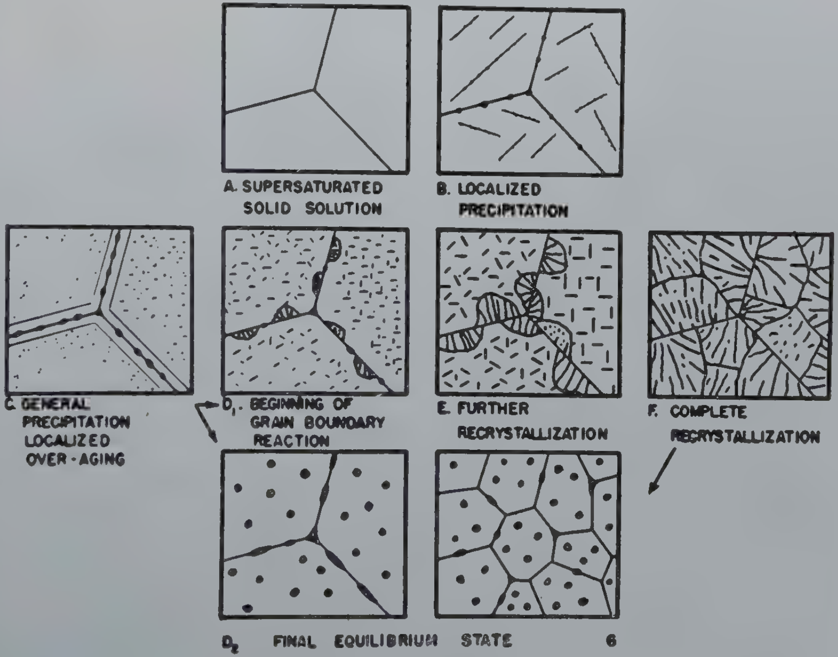
A. SUPERSATURATED SOLID SOLUTION
B. LOCALIZED PRECIPITATION
C. GENERAL PRECIPITATION LOCALIZED OVER-AGING
D₁. BEGINNING OF GRAIN BOUNDARY REACTION
E. FURTHER RECRYSTALLIZATION
F. COMPLETE RECRYSTALLIZATION
D₂ FINAL EQUILIBRIUM STATE
6

Fig. 1. General sequence of structural changes taking place during aging (Geisler).

## age-hardening

Geisler has presented an orderly correlation of the property changes and structural changes that take place during aging. It is shown that, qualitatively at least, it is possible to explain all the observed features of aging curves for various properties on the basis of simultaneous effects of the several structural changes that are known to occur. The general sequence of structural changes may take either of two courses, depending on whether or not recrystallization occurs at the grain boundaries ("discontinuous precipitation"). These two sequences are shown schematically in Fig. 1.

Geisler and Newkirk have applied the type of analysis suggested above to an investigation of the sequence of structural and property changes during aging of a permanent-magnet alloy, Cunico. Changes in hardness, electrical resistance, and magnetic properties were interpreted in terms of attainment and loss of coherency, the grain-boundary recrystallization reaction, and depletion of the solute concentration in the matrix.

Guy, Barrett, and Mehl studied the aging of polycrystalline and single crystal samples of copper-beryllium alloys by means of hardness, X-ray diffraction, electrical resistance, and micrographic techniques. Guinier-Preston zones were found to form on cube planes of the matrix, in agreement with Guinier and Jacquet's work. Guinier and Jacquet and these authors found that the hardening in this system may be attributed to coherent precipitation. They have demonstrated further that aging is accelerated by quenching strains and that it is more rapid in polycrystalline specimens than in single crystals.

Guinier and Lambot have investigated the X-ray diffraction patterns obtained from single crystals of Al-Si-Mg and Al-Cu-Si-Mg alloys using monochromatic radiation. In Al-Si-Mg alloys it is found that the coherent precipitate forms as thin rods parallel to the cube direction in the matrix. In the stable precipitate a <110> direction is parallel to the cube direction of the matrix. The authors show that coherent segregation having such orientation relationships could occur without introducing large strains. In the Al-Cu-Si-Mg alloy there was a super-position of the phenomena previously observed in Al-Cu alloys and the behavior described above.

Morrogh and Williams have discussed the production of nodular graphite structures in cast iron, which leads to a remarkable degree of ductility in this heretofore brittle substance. Addition of cerium in hypereutectic alloys resulted in nodular structures, even in alloys of low nickel contents. It appears that cerium ties up the sulphur and consequently a nodular structure results.

## diffusion

A number of investigations have been completed in which "uphill" diffusion was measured. One of the most interesting of these was carried out by V. Daniel on the alloy $Cu_4$ Fe $Ni_3$. Below 800C, this alloy breaks up into two face-centered cubic phases having the same proportions of iron and nickel but different copper contents. When the alloy is quenched into the two-phase region, the X-ray powder diagrams may be interpreted in terms of a periodic variation of copper concentration in one dimension. The amplitude of the wave (the maximum copper-concentration difference) changes rapidly with time relative to the change in wave length (the distance separating adjacent copper-concentration maxima) until the equilibrium or maximum amplitude is reached. Then the wave length continues to increase slowly with time. The increase in amplitude with time corresponds to the "uphill" diffusion process while the increase in wave length corresponds to a grain-growth process. Daniel calculated the dif-

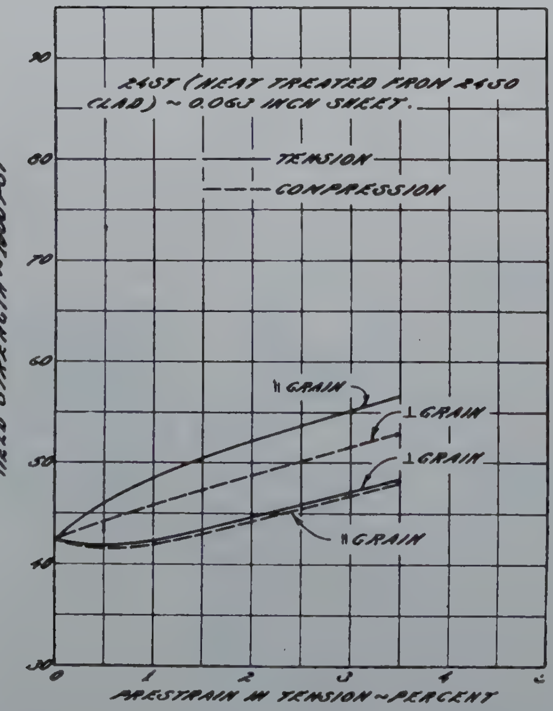

Fig. 2. Effect of prestrain in tension on compressive and tensile yield strength of 24ST (Klingler and Sachs).

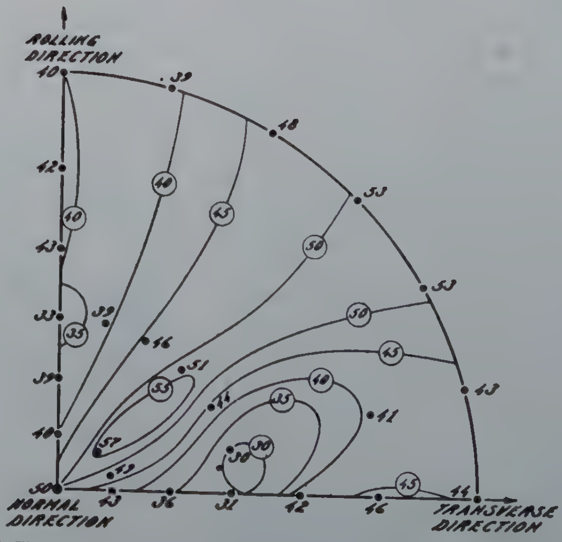

Fig. 3. Stereographic projection showing the plastic anisotropy ($-\epsilon^2/\epsilon^1 \times 100$) for various orientations in 24ST plate (Klingler and Sachs).

fusion coefficients for the uphill diffusion and found qualitative agreement with Becker's theory for diffusion in such alloys. This theory was based on the assumptions of ideal entropy of mixing and the nearest neighbor hypothesis.

Darken has shown that if two austenites of the same carbon concentration but different alloy contents are welded together, the concentration of carbon on either side of the weld becomes adjusted by "uphill" diffusion until the activity of carbon becomes identical on either side of the weld. This, of course, corresponds to a substantial difference in carbon concentration.

Birchenall and Mehl have reported the self-diffusion rates in alpha and gamma iron. They calculate that at the transformation temperature the rate of self-diffusion in alpha iron is about 100 times greater than the rate in gamma iron.

Fisher, Hollomon, and Turnbull have applied the absolute reaction-rate theory to diffusion in two-component systems. They show that it is not possible to calculate variation of interdiffusion coefficients with concentration without making some explicit assumption about the variation of the activity coefficient of the activated complex with concentration. Further, they show that in alpha brass, the variation of diffusion coefficients with concentrations does not favor any particular diffusion mechanism.

## powder metallurgy

Shaler and Wulff calculated the rates of shrinkage of copper compacts, assuming a model in which sintering proceeds by the flow of metal under the influence of surface tension, modified by gas pressure. Fair agreement was found between calculated and measured shrinkage rates. The same authors in a note have suggested that the origin of the viscosity in their sintering mechanism arises from preferential self-diffusion of vacancies in the lattice, under the influence of stress.

Schwarzkopf discussed the mechanism of sintering and concluded that plastic flow plays an important role in all stages of the sintering mechanism. He also pointed out that surface diffusion and plastic flow do not take place independently of each other.

A highlight of the year was the first international powder metallurgy conference in Graz, Austria. Over seventy papers were presented of a theoretical or technical nature. The collection is to be published by the Austrian Chemical Society.

## deformation

Although some additional work has been done verifying the "laws" of plasticity for isotropic materials, the principal advances have been in their extension to anisotropic materials. J. C. Fisher has devised a theory of plastic anisotropy applying to metals having cylindrical symmetry. L. R. Jackson, K. F. Smith, and W. T. Lankford have developed a theory of plastic anisotropy for the type of symmetry to be expected in rolled sheet or plate. The behavior predicted by both of these theories was in better agreement with experimental results than the predictions of the plasticity laws for isotropic materials. R. Hill verified his anisotropy theory by comparing its predictions with the results of Korber and Hoff. The results of this work suggest that it will soon be possible to predict the deformation behavior of commercial anisotropic materials from the results of simple tests.

Some of the difficulties of extending the plasticity laws to apply to anisotropic materials are pointed out by L. J. Klingler and G. Sachs. The plastic anisotropy due to cold stretching of 24ST sheet was investigated. The results indicate that the tensile yield strength is lowered if the prior axial strain is compressive, regardless of the stress state producing the prior deformation. The degree of anisotropy and the Bauschinger effect both increased with increasing prestrain up to about one per cent and then apparently remained constant (Fig. 2). These results suggest that anisotropy and the Bauschinger effect may be simply different manifestations of the same phenomenon, or at least that they are intimately related.

They also dealt with the anisotropy of annealed metals arising from preferred orientation. Tensile specimens cut from 24ST plate in various directions showed different amounts of contraction in different directions perpendicular to the tensile stress axis. The variation of deformation properties, although having nearly orthotropic symmetry, was so complex that it seems unlikely that a mathematical expression representing it can be devised readily (Fig. 3).

### • alternating loads

The application of alternating tensile and compressive plastic strains of equal magnitude showed that the full strain hardening and Bauschinger effect were developed in the first cycle of tension and compression (for moderate strains) and then remained es-

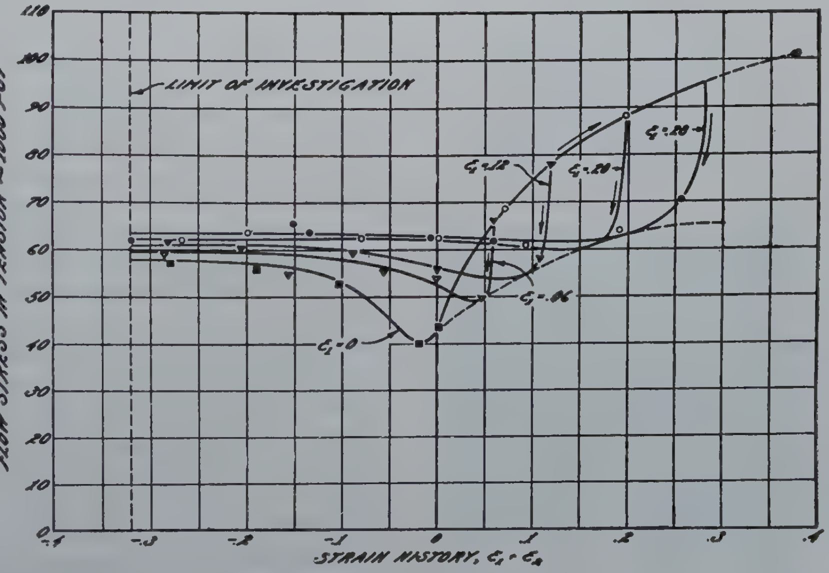

Fig. 4. Effect of strain history on the yield strength (at $\epsilon = .002$) of 24ST (Liu and Sachs).

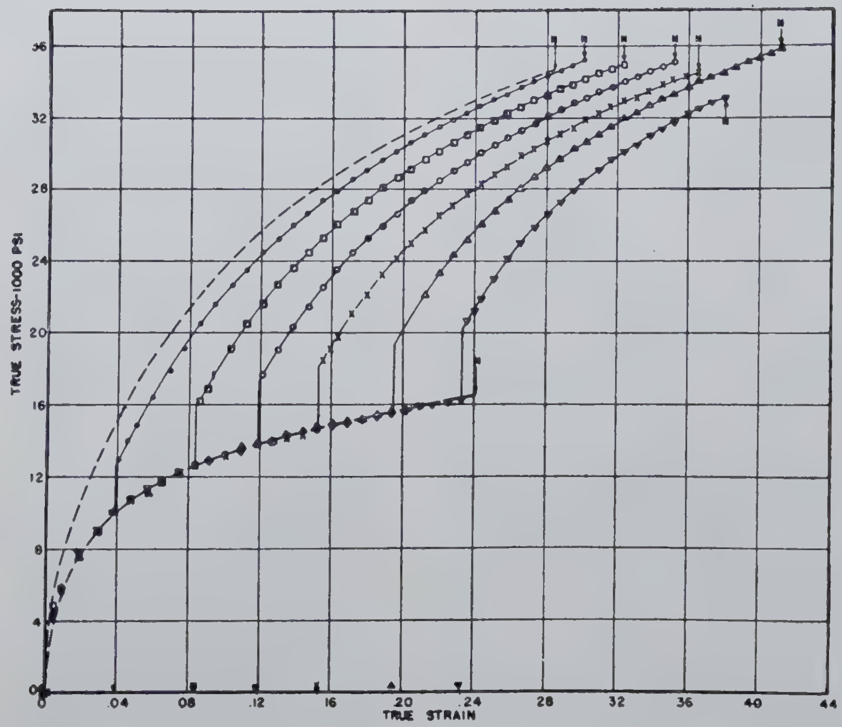

Fig. 5. Effect of prestraining at 292 K on $\sigma-\epsilon$ curve at 78 K for 2S-O (Dorn, Goldberg and Tietz).

sentially constant or decreased slightly.

Additional information about the Bauschinger effect was obtained by measuring the yield strength in tension after compression and in compression after tension. The Bauschinger effect in tension after compression increased much faster and to a much higher value if the prior compression was preceded by tension (Fig. 4).

A few investigations carried out in 1948 throw some light on the validity of the "mechanical equation of state" concept. Experiments by J. E. Dorn, A. Goldberg, and T. E. Tietz show that flow stress depends markedly on the temperature at which the prior strain was introduced (Fig. 5). Similar results had been found by Orowan. The possibility remains that the equation of state concept might be valid if an "equivalent strain" (causing the same strain hardening) is used in place of the actual strain or if strain is measured by the work done on the specimen instead of in the conventional way. Application of these hypotheses to Dorn's and Orowan's data showed rather good, but not perfect, coincidence along the entire length of the curves.

Nucleation theory applied to slip indicates that the mechanical equation of state might be applicable only after disappearance of transient effects following a change in stress, strain rate, or temperature. Preliminary experiments indicate that such transient effects do exist.

### • creep

Andrade has suggested that the occurrence of third stage creep at small strains may be due to the onset of recrystallization, and he shows that the phenomenon (Fig. 6) occurs definitely in lead.

In 1935, R. W. Bailey showed that the creep resistance of certain steels first increases and then decreases again with prior tempering. Instead of continuous deterioration of creep resistance during service life, there is a strengthening effect during the early stages (perhaps during the entire life of the part) if secondary hardening occurs. Recently, J. Glen thoroughly explored utilization of the phenomenon of secondary hardening in steels of several compositions and for a wide variety of testing conditions. It was found that the optimum contents of carbon and of alloying elements depend on the testing conditions. The amount of strengthening and the rate of subsequent deterioration depend on other variables, such as carbon content and permissible total plastic strain.

### • slip phenomena

Most investigations of the phenomenon of slip have been on single-phase metals. R. W. K. Honeycombe and W. Boas have examined slip bands on a polished surface of alpha-beta brass. At one per cent strain, many slip bands occur in the alpha grains but none in the beta grains. Even at large strains (27%) there is little slip in the beta grains, while heavy multiple slip and rumpling of the surface has occurred in the alpha grains.

Hibbard, and Boas and Hargreaves have studied the important problem of the nature of slip near grain boundaries.

J. E. Burke and C. S. Barrett have investigated the nature of the strain markings that appear after polishing and etching deformed metals. It was shown that the thick deformation lines observed in severely deformed 70-30 brass consist of closely-spaced groups of fine lines. Weak deformation lines could be revealed after deformations as small as one per cent. However, the conclusion that strain markings can be found whenever slip has occurred does not appear to be justified, as pointed out in the discussion.

W. R. Hibbard, R. W. Fenn, H. Margolin, and H. P. Moore have investigated the effect of composition on the ease with which deformation lines can be revealed in some copper alloys. The deformation required to produce the markings in 20 per cent of the grains decreased with solute additions up to about half the solid solubility limit. Further additions of solute increased the amount of deformation required. This variation could not be correlated with changes in other properties.

There have been high hopes that the process of slip in metals could be understood more completely by studying it in transparent nonmetals, such as silver chloride. Recent work by J. F. Nye showed that the glide planes causing the observed birefringence never coincided with a crystallographic plane of low indices.

### • twinning

Extending the early work of Reusch on calcite, R. I. Garber has utilized optical methods to study the mechanism of twinning. The surface contour of a highly polished surface loaded by a spherical lens was studied by means of interference fringes using the arrangement shown in Fig. 7. The fringe patterns show the contour of a surface in which a twin is forming (Fig. 8). The first twins to appear, disappear on release of the load (hence the term "elastic twins"), while higher loads produce twins that do not disappear on release of the load.

W. P. Mason, H. J. McSkinnin, and W. Schockley found that during the formation of a twin there is an oscillation of the loaded surface having an amplitude of about ½ to 2 A and a period of 1 to 3 microseconds. This was interpreted as evidence that twinning proceeds by the passage of dislocations through the crystal at the speed of sound.

A. V. Stepanov has attempted a rationalization of the identity of twinning planes on the basis of elastic anisotropy. The results indicate that the criterion may be generally applicable. A. H. Cottrell has explained the yield point as being due to a cloud of solute atoms surrounding a dislocation and preventing its motion until a higher stress is reached than that required for propagation of a free dislocation. If this explanation is correct, discontinuous yielding should occur in single crystals of all materials for which it is observed in polycrystals.

Discontinuous yielding has, in fact, been observed in cadmium crystals by Cottrell and Gibbons and by several previous workers. However, the lack of consistency in the conditions reported to be necessary for appearance of the phenomenon leads to some doubt about the interpretation.

Cross slip has been observed in brass crystals oriented for single slip according to the classical analysis. The cross slip bands were traces of octahedral planes containing the operating slip direction of the usual slip bands. We considered the cross slip to be compensatory to the tendency for rotation of the crystal under gripping conditions which prevented this rotation. D. C. Pack, W. M. Evans, and H. J. James have investigated theoretically the velocity of propagation of shock waves in steel and lead.

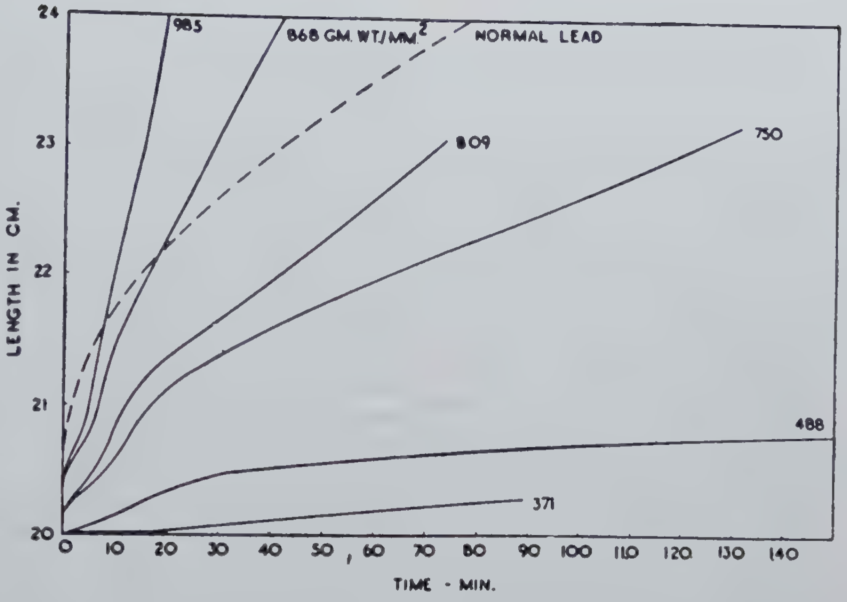

Fig. 6. Creep of very pure lead that recrystallized under stress (Andrade).

For iron, the calculated velocity of plane elastic waves is higher than that of shock waves, while in lead the reverse is true. The results were confirmed experimentally. In lead, the shock wave is damped, causing its velocity to decrease to less than that of plane elastic waves within a few cm of the source.

Ph. Olmer has investigated the velocity of propagation of transverse and longitudinal elastic waves in a single crystal of aluminum by analysis of intensity measurements of X-ray diffuse scattering. The phase velocities of longitudinal and transverse elastic waves were calculated as a function of their wave lengths. For long wave lengths the velocities are in good agreement with those observed in mechanical tests. From the variation of the velocities with wave length it is deduced that the propagation of transverse elastic waves in aluminum depends only on the interaction of each atom with its nearest neighbor. For longitudinal waves, on the other hand, the data are interpreted as indicating that the wave propagation depends on the interaction of second neighbors at least, and perhaps others. T. S. Kê has investigated the relaxation spectrum of tantalum over the range 25 to 450C by torsion-pendulum studies of wire specimens. Internal friction peaks were found to be due to the stress-induced preferential distribution of interstitial carbon at octahedral positions, of interstitial oxygen at both octahedral and tetrahedral interstitial sites, and of nitrogen at positions similar to those of oxygen atoms.

Kê has conducted another series of

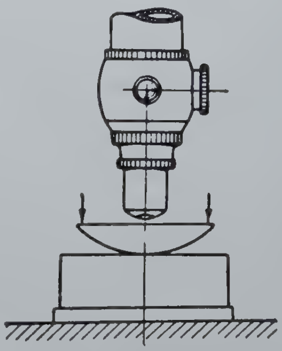

Fig. 7. Experimental arrangement for deformation study, using interference fringes. The crystal rests on a soft pad and is loaded by the lens. The crystal surface is examined through the lens by reflected light (Garber).

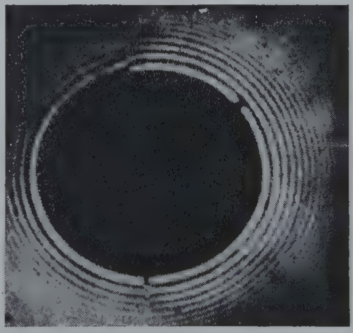

Fig. 8. Fringe pattern from surface of calcite in which a twin has formed (Garber).

torsional vibration studies on the anelastic effects in alpha iron. He found an internal friction peak at 20C due to the stress-induced preferential distribution of interstitial nitrogen. The 225C peak previously reported by Snoek and by West was found to be caused by the stress-induced diffusion of nitrogen within stress regions of an unknown nature created in the specimen by cold work. Another peak was found at 490C caused by grain boundary relaxation.

Entwistle followed the damping capacity of some precipitation-hardening alloys during the aging process. The damping capacity of duraluminum was found to be low immediately after quenching from the solution temperature, rising to a maximum and then decreasing as the aging process continued. This paper should be compared with that of R. F. Hanstock, in which the effect of vibration on the precipitation hardening of R. R. 56 was studied. Hanstock draws the general conclusion that vibration causes an acceleration of the natural process of aging. The results indicate that the damping capacity of this alloy decreases to a minimum and then increases as aging continues. This is directly opposed to the results reported by Entwistle for the same alloy and heat treatments.

In his study of the thermodynamics of irreversible processes, Carl Eckart treats the theory of elasticity and anelasticity. He predicts that a pure isotropic substance will have a minimum of five lines in its relaxation spectrum. The addition of impurities and anisotropy would increase the number of such lines.

### • fatigue

E. Epremain and E. F. Nippes found that the relative order of effectiveness, of solute elements in alpha iron, in increasing the fatigue strength is Ti, Mo, Si, Mn, Ni, Co, and Cr. The effectiveness varied inversely with the extent of solid solubility. Changes in the damping capacity were correlated with cold working and gave a qualitative indication of incipient fatigue fracture.

J. L. Zambrow and M. G. Fontana investigated the fatigue properties of a number of aircraft alloys at temperatures ranging from 25 to minus 196C and found the endurance limit to be greater at low temperatures in all cases.

The Army Air Corps made available the results of Hempel's work on low-temperature fatigue tests of steel. Low temperature increased the fatigue strength of all steels tested using smooth specimens. The effect was much smaller for notched-bar specimens.

The effect of prior cycles of stress on the brittle transition temperature and brittle fracture strength in impact testing of SAE 1020 was studied by C. W. MacGregor and N. Grossman. The greater the number of cycles at a given stress level, both above and below the endurance limit, the higher the brittle-transition temperature and the lower the brittle-fracture strength.

S. I. Liu, J. J. Lynch, E. J. Ripling and G. Sachs have studied the effect of cyclic strains of 24 ST in the range $\varepsilon = \pm 0.01$ to $\pm 0.30$, these strains causing fracture after one to seven cycles. The fracture stress and retained ductility decreased with both the magnitude and number of cyclic strains, while the total ductility increased.

### • fracture

Zener has presented evidence indicating that the stress concentration necessary to initiate fracture arises from slip bands stopped by grain boundaries, precipitate particles, and the like. Thus the locus of fracture stress has no meaning in the absence of deformation. In view of the large volume of literature based on both the statistical concept and the fracture-stress curve concept, such conclusions are significant and controversial.

G. Irwin utilized the statistical concept in developing a condition for fracture instability. The condition equates the rate of release of stored elastic energy by an advancing crack to the rate of work done in advancing the crack. Interesting experiments were reported on crack progression from slits in thin aluminum foils.

The effect of stress state on the fracture of metals was discussed by J. E. Dorn in terms of a fracture-stress curve. He presented data on the fracture of aluminum and magnesium alloys under biaxial stresses. These results approximated the predictions of the maximum shear-stress law.

Lynch, Ripling, and Sachs published results that show that the ductility and fracture stress of 24 ST in tension is increased with prestraining by drawing, extrusion, torsion, and compression. These results are further evidence of the validity of the hypothesis that retained ductility is improved by prestraining under hydrostatic compression. In discussing this paper, Bridgman reported increasing the strength of commercial piano wire by drawing under hydrostatic pressure of 180,000 psi. The retained ductility in a simple tension test was 0.29 with 530,000 psi tensile strength and 720,000 psi fracture strength.

Liu and Sachs found that if a tension test is interrupted by an interval of straining in compression, the total natural strain to fracture increases with increasing compressive strain and is greater if the compression is inserted later in the test.

McAdam, Geil, Woodard, and Jenkins have concluded that the increase in the fracture stress of notched-tensile specimens with increase in the sharpness of the notch is due to increase in the ratio of transverse to longitudinal tensile stress, not due to a size effect. McAdam, Geil, and Cromwell have pointed out that triaxiality changes during the flow of a notched or unnotched specimen in a tensile test and therefore the experimental fracture stress should be corrected for this effect. They also state that deformation in a ductile metal continues after fracture starts, and therefore the breaking stress obtained by dividing the load at fracture by the cross sectional area after fracture gives a value much higher than the true fracture stress.

C. Gurney studied the delayed fracture of glass under tension, torsion and radial pressure, and compression. He found that fracture occurred in equal times when the largest principal tensile stresses were equal, regardless of the manner of stress application. The stress-corrosion cracking of brass in an ammonia medium was found to exhibit the same type of relationship between time for fracture and maximum principal tensile stress, as did the fatigue fracture of rotating-beam specimens of glass.

J. C. Fisher discussed the fracture of liquids from the standpoint of nucleation theory. Ordinary liquids were said to fracture by bubble formation, sub-cooled liquids, such as glass, by crack formation. Fracture strengths were calculated and compared favorably with the maximum experimental values.

Zagorodskikh studied the effect of superimposed tensile and compressive stresses on the notched-impact strength of low-carbon steel. Tensile stresses, even those close to the yield point, did not effect the temperature of brittle transition. Compressive stresses lowered the brittle-transition temperature range.

### structure and binding

Pauling's concepts of metallic binding have been further developed. Essentially he considers that interatomic forces in metals are predominantly due to covalent bonds resonating among the available interatomic positions. Electronic conductivity and other characteristic properties of metals may be described in terms of the transfer of the positive and negative charges from atom to atom accompanying the resonance of valence bonds. It is shown that the valence-bond treatment of metals correlates well with some properties of metal crystals and the formulæ of intermetallic compounds.

However, Hume-Rothery considers that these views are inconsistent with the valencies which must be ascribed to the transition elements in brass containing manganese, iron, or nickel, in order to explain the observed isothermal phase boundaries.

The new technique of neutron diffraction has received considerable attention. A valuable review of the theory, procedure, and results has been published by Wollan and Shull. Weber and Arnold have shown that preferred orientation in aluminum can be investigated conveniently with monenergetic neutrons as well as with X rays.

Hibbard and Yen have considered the flow directions and slip systems necessary to give stable-end orientations for various types of deformation including rolling, tension, and compression. Their theory is successful in predicting the end orientations actually observed, particularly in the case of metals with cubic structures.

### magnetic and electrical properties

Starting from the domain theory, Stoner and Wohlfarth, and Kittel have developed theories for the high coercive force exhibited by a suspension of a fine magnetic powder in a nonmagnetic matrix. The matrix may be air or a nonmagnetic phase of a polycrystalline alloy. Such a small ferromagnetic particle consists of a single domain so that reversal of the direction of magnetization cannot take place by growth of an existing domain.

Many magnetic properties of alloys are known to be influenced strongly by ordering, aging, and allotropic change. Snoek and Fast have shown that in the absence of such changes the initial permeability of pure nickel still varies with low-temperature heat-treatment. Small mechanical shocks or demagnetization of the sample gave a lower initial permeability that was independent of heat-treatment.

Discovery of a semiconductor triode, the transistor, by Bardeen and Brattain suggests that in the future the attention of metallurgists will be directed more than at present toward the study of semiconductors such as germanium, selenium, and their alloys.

### surface phenomena

One of the most important contributions, during 1948, on the surface properties of metals was made by C. S. Smith, who developed the concept that the nature of many metal microstructures derives from the approach to equilibrium between grain interfaces. From the equilibrium angles he was able to express the interfacial energy between grains of the same phase and between adjacent grains of different phases in terms of one reference interfacial energy which is not known. Fisher has suggested a method of determining this reference energy.

McBain and associates have reported experiments that indicate that surface forces are of longer range than has previously been suspected, probably by virtue of a chain interaction through matter. For example, they have found that the lattice parameter and orientation of nickel films on copper is identical to that of the base metal to thicknesses of 30,000 A. The same effect has been observed for a number of other metals.

A large number of papers have appeared on stresses in electrodeposits. Among these is that of Wyllie, who estimated the magnitude of the stresses in a number of such deposits. His results appear to confirm Bozorth's theory, which ascribes preferred orientation in thick electrodeposits to deformation resulting from stresses arising from the deposition conditions. Wyllie interprets the origin of these stresses in terms of the evolution of hydrogen codeposited with the metal.

### corrosion

Polarography has been adapted to the study of corrosion by Van Rysselberghe and collaborators. A small sheet of metal is placed in the cell, with no contact with the electrodes. Corrosion by various substances, such as oxygen, hydrogen peroxide, acids, etc., is detected by measuring their reduction currents in solutions of electrolytes. As these reducible substances are consumed by the corroding metal, the dissolution of the metal may also be followed, to a certain extent, by the polarographic reduction current of the metallic ions.

Hickman and Gulbransen have continued their electron diffraction studies on the structure of oxide films formed on various alloys. They report that there is no unique structural change in the oxide film formed on copper-nickel alloys at the composition where they become passive to corrosion. This suggested that the mechanism of gas-phase oxidation and corrosion are basically different. They have also studied the rates of oxidation of a series of nickel-chromium alloys by means of the vacuum microbalance. They report that the 80% nickel-20% chromium series appears most promising from the standpoint of oxidation resistance. Silicon additions further improve this property.

Lacombe and Yannaquis have found that the rate of intergranular chemical attack or electrolysis decreases markedly in high-purity aluminum as the orientations of adjacent grains approach each other. Therefore, they conclude that intergranular corrosion in this instance must be attributed to the disorder at grain boundaries resulting from the disorientation rather than to impurities at the boundaries.

Leslie and Fontana have studied the mechanism of the spectacularly rapid rate of oxidation of certain Cr-Ni-Mo alloys at high temperatures. They attribute the rapid rate to the accumulation of volatile $MoO_3$ on the metal surface. Oxidation is accelerated above the dissociation temperature of the oxide (815C). Other volatile oxides (e.g. $WO_3$) accelerate oxidation similarly when present on metal surfaces.

Theories for the passivation of stainless steels and similar alloys remain in a state of flux. Mahla and Nielsen have analyzed chemically and by electron diffraction thin-oxide films from passivated stainless steels, and considered that both chromium and iron are primary constituents of the film. These authors attribute passivation to these oxide films. On the other hand, Hackerman and Marshall conclude that the noble potentials obtained with oxide films on chromium need not be identified with passivity and that the metal can exhibit a noble potential even when no oxide can be detected on its surface. Parshad and Verman propose that a hydrogen film is formed between the metal and the oxide film. A somewhat similar mechanism is proposed by Guitton for chromium-nickel and chromium-manganese alloys pretreated with hydrofluoric acid-nitric acid; this pretreatment results in an increased passivity that is attributed to penetration of hydrogen into the lattice, followed by adsorption of oxygen.

Contributions that appear to have a direct bearing on the basic concepts of metal behavior have been emphasized in this review. Many valuable papers reporting accumulation of data, properties and treatments of complex or commercial alloys, and progress in the development of commercial methods have not been included, despite their importance in many fields of activity. In general, the survey has been confined to the results of published research.

The authors' capacity has been largely editorial. They are indebted to R. P. Carreker, J. C. Fisher, A. N. Holden, J. H. Hollomon, J. D. Lubahn, R. A. Oriani, and G. W. Sears, who contributed sections of this review.

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## Thermal Expansion of Earth Materials Studied

Lack of needed fundamental thermal-expansion data of highest accuracy on many earth materials has become of enough importance to justify the thorough research project which is being undertaken at Rensselaer Polytechnic Institute, Troy, N. Y. Such data are needed in geophysical and mineralogical studies and will also be useful to industries that use and manufacture ceramic materials such as glass, tile, clay products, refractories, electrical insulators, and resistors, etc. Similar data have long been essential in working with metals and alloys, both in the laboratory and in solving everyday engineering problems. Fundamental data on the earth materials will be obtained over a period of several years by Professors J. L. Rosenholtz and D. T. Smith, who recently set up special testing equipment in the department of geology and mineralogy and have started on the project.

The investigators will determine the linear thermal expansion of rocks and crystallographically oriented mineral specimens at temperatures ranging from 20 to 1400 C. Mineral transformation temperatures will also be determined. Specimens are ¼-in. square prisms ½ in. long which are prepared by sawing mineral crystals parallel to their crystal axes. Diamond saws are used for most minerals. They are placed in the closed end of a 20-in. quartz dilatometer tube. This end of the tube is in a small cylindrical electric furnace and the open end extends horizontally out of the furnace and into an Invar sleeve on a follower unit that was specially designed by the testing equipment department of The Baldwin Locomotive Works.

The miscroscopic changes in length of the ½-in. specimens with increasing temperature are measured by the Invar follower unit which incorporates a Microformer (miniature transformer with movable core) extensometer and recorder that were recently developed by The Baldwin Locomotive Works. The core of the Microformer extensometer is activated by an Invar lever which is in turn activited by a quartz rod extending through the quartz tube to the end of the specimen in the furnace. Expansion of the specimen may be magnified up to approximately 2000 times by the Microformer recorder which automatically draws a deformation-time curve on the recorder chart. This equipment incorporates a self-balancing transformer bridge which is sensitive to length changes of the order of two millionths of an inch. Displacement of the core of the extensometer follower unit in either direction unbalances the bridge circuit. The unbalanced signal is amplified and drives a servo motor which, in turn, rotates the recorder drum and at the same time moves the core of the Microformer recorder to a position where its output again balances that of the Microformer extensometer. Temperatures are recorded and controlled by a special Leeds and Northrup Micromax unit which makes it possible to heat and cool at predetermined rates and to hold any pre-set temperature. This instrument draws a time-temperature curve.

The investigators plan to supply a steady stream of new data which will appear from time to time in technical journals. They expect to improve the accuracy of thermal data on many materials as well as to determine the thermal properties of other materials for which no data are available. Data for a single specimen may require a day, including time for preparing the test. If several specimens of each material are tested to check results, the total time required for each material may be several weeks since some minerals must be studied in three directions, requiring at least nine determinations plus the time for cutting and for setting up.

Plans have been made to obtain data on all important minerals and rocks over a period of years. Although it is a full-time project only during the summer, the fact that the equipment is fully automatic in operation after being set up and needs no attendant, makes it practicable to obtain a large volume of data during the scholastic year.

1 **Iron ore** comes from large open-cut mines like this corner of the Hull-Rust mine of the Oliver Iron Mining Co. at Hibbing, Minn., and is transported by boat over the Lakes and by rail from Lake ports to . . . .

Photo Courtesy U. S. Steel.

2 **stock piles** at the blast furnace. The ore is carried by crane to the blast furnace where it is made into pig iron, the raw material for steel. Steel is made in open hearths, electric furnaces, or in . . . .

# Iron and Steel Producers . . .

## . . . set records—expansion, technological developments responsible

By **WALTER CARROLL** • GENERAL METALLURGIST, REPUBLIC STEEL CORP.

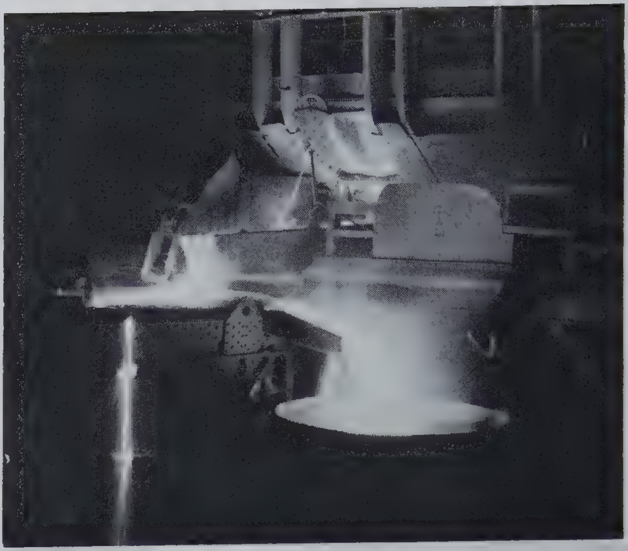
Between cross currents of economic factors and international expediencies the iron and steel industry in 1948 made an outstanding contribution to the general economic picture. Were it not for an unfortunate episode during the month of April involving a temporary shortage of coal, 1948 would have been an all-time record year in output. Exceeded in no previous peacetime year, the production of iron and steel in 1948 totaled some 88,500,000 tons. That it was a worthwhile effort of no small magnitude is evidenced by the fact that in three and one half years following the war, this nation has produced as much steel as in the five years preceding the war. This figure of 88,500,000 tons is 68 per cent greater than that for 1939. It is a far cry from the 31,751,000 tons produced in 1938. Likewise, shipments of finished steel products have reached the all-time high of 66,000,000 tons. There are several factors contributing to the fine accomplishment in 1948, and in the attainment of such an outstanding over-all record there were numerous individual records made in the several divisions of the industry.

The steel industry continued its peacetime expansion program with a record expenditure during 1948. While the largest part of the increase in expenditures during the past year should be attributed to the rapid increase in costs of equipment and construction that forced upward revision of the original plans, the outstanding feature is that the 14 per cent increase of 1948 over that of 1947 is quite a bit larger than the 3 per cent increase in expenditures for new equipment and plants in the whole manufacturing and mining industry.

### raw materials

Most outstanding in 1948 was the movement of iron ore from the Upper Lakes. There is no gainsaying that a considerable amount of pride can justly arise from the fact that the 1948 tonnage of ore unloaded at the Lower Lake docks was the largest ever moved in peacetime. The tonnage of roughly 83,000,000 tons, exceeded only in the wartime years of 1942 and 1943, is better than the 82,696,656 ton average of the five war years. Due credit should be given to those concerned with the actual details of the mining and shipping prob-

3 **Bessemer converters,** or a combination of the three. The Bessemer converter in the foreground is in blow; in this case, making an artificial scrap that will be charged into an . . . .



4 **open hearth** where the steel is made. This furnace is being tapped into a ladle, the slag overflowing to the pot at the right. The ladle will be lifted by a crane and the . . . .

lems, especially for being in a position to take full advantage of the early start as well as the phenomenally fine weather of the fall season.

Interest in New York ore continues apace. The 1948 production of over 2,000,000 tons could have been larger had the necessary labor been available in that region.

Postwar demands for steel products, following closely on the heels of World War II, have directed the attention of the iron and steel industry to the iron reserves of the United States in particular, as well as the Western Hemisphere in general. In northern New York, Republic Steel Corp. and Jones & Laughlin Steel Corp. have undertaken extensive programs involving exploration of new and old areas. Likewise, exploration is underway in Alabama, California, Missouri, Texas, and Utah. Continued exploration and development work is being done in Venezuela and Brazil by U. S. Steel Corp. and Bethlehem Steel Co. The latter is likewise obtaining quite a bit of iron ore from Chile and the west coast of South America.

Investigations in the beneficiation of taconites in the Lake Superior region were continued on an active basis during 1948. While the answer has not been realized as yet, the pilot plants now working on beneficiation showed promise of solving this intriguing problem within a few years.

The consumption of scrap during 1948 reached an all-time high. During the early months of the year stocks had dwindled to a short supply, with some plants existing on a hand-to-mouth basis, with an added complication in the deterioration of the quality as the year progressed. The last few months of the year there was an increase in the amount of scrap available.

The year closed with a good inventory of scrap on hand at most plants. However, the quality of the scrap left did not improve with the quantity. Indications point to a tight scrap situation for some time to come, or as long as the country's industrial activity maintains anything approaching its current high level.

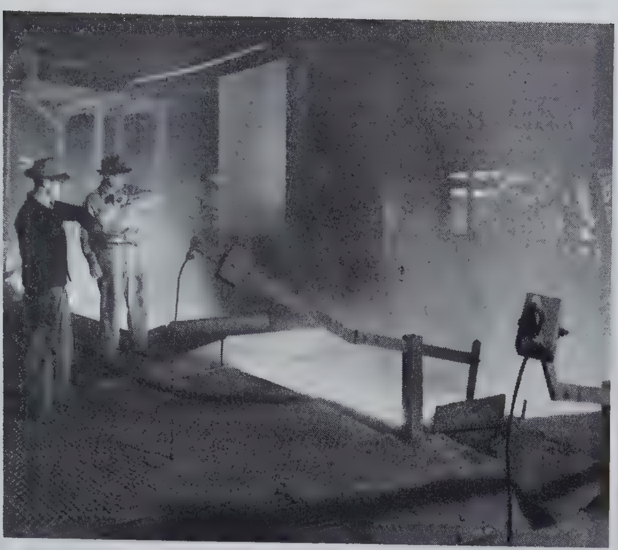
Some scrap was brought in from the European battle fields. While the amount was relatively small, it did have its effect by easing the scrap situation in some areas near the Atlantic seaboard. The problems involved in making available any quantities of scrap from the Pacific areas have not yet been solved, due largely to the difficulties of collection and transportation. However, it is felt that these difficulties are not insurmountable.

Fuel oil in 1948 was involved in the crisscross of technical considerations, economic factors, and international problems. During the year the importation of creosote from Great Britain tended to ease up the position of the British pound, but had its economic repercussions in this country. The imported creosote had its effect on the tar produced by American coke-products plants. This tar being diverted to use as open-hearth fuel lessened the use of the various grades of fuel oil. That economic chain reaction plus the fine weather in the fall months, easing the demand for domestic heating purposes, brought about an increase in the available supplies of fuel oil, together with a lessening in costs. The year closed with quite a bit of fuel oil held in mill storage tanks for use during the winter period with its difficult transportation problems.

Manganese supplies during 1948, while not overly abundant, have been sufficient for the year's operations. During the first nine months of 1948, importations of manganese ore of metallurgical grade were 1,058,487 tons, with a manganese content of 499,643 tons, which was at a rate with only a slight margin over the demands of this country. It is of interest to point out that manganese shipments into this country came from the USSR, India, Union of South Africa, Brazil, and the Gold Coast, in that order of importance. Production of domestic manganese which, while not large in comparison to the importations, was of considerable assistance in the problem of metallurgical manganese.

Sponge iron investigations were continued during 1948. However, the results were on much the same scale as before. Sponge iron still remains an academic subject still far removed from a production basis.

5 **molten steel poured** into molds to form ingots. To make the ingots uniform in temperature they are placed in . . . .



Photos courtesy U. S. Steel

6 **soaking pits** until they reach the proper temperature throughout for working in the rolling mills to make steel products.

### blast furnaces

Blast furnaces in 1948 set a new record for the production of pig iron, thus keeping pace with the increase in the demand for that product. Increase in capacity continued in 1948 with new stacks being completed and put into operation. Among those were Numbers 11 and 12 at the South Chicago works of Carnegie-Illinois, and Furnace H at the Sparrows Point plant of the Bethlehem Steel Co., also a new stack at the Ford Motor Co. and one at the Pittsburgh Steel Co. Two stacks at Mingo Junction, Ohio, were reconditioned and put into operation by the Wheeling Steel Corp. Projected for the near future are additional stacks including a charcoal furnace, still in the construction stage, at Rusk, Texas.

Typical of the blast-furnace division, along with the rest of the industry, was its constant striving for increased tonnage and lower costs through improved methods. These efforts for improvement have given support to changes that at one time would have been considered quite radical.

Chief among the changes suggested for some time was the use of carbon blocks in the hearth of the blast furnace. The year 1948 saw the installation of 24 hearths with carbon bottoms, thus bringing the total number of installations up to sixty. This means that in the United States one fourth of the blast furnaces are built with hearths of carbon in some form or other. While most of the new installations carried the carbon lining up to the vicinity of the tuyeres, one furnace at Chester, Pa., in 1948 was equipped with carbon up to the mantle, which, incidentally, was in line with that of previous European installations. The history of this lining will be watched with interest.

Although without the benefit of a completed campaign by any furnace equipped with carbon, 1948 did bring forth the feeling that the carbon hearth is an integral part of the modern blast furnace. However, the use of carbon in the crucible will require careful and painstaking co-operation of the blast furnace operators with the designers and the carbon-block producers.

It became apparent in 1948 that the use of carbon is not a panacea for all blast furnace trouble, as it does not abolish the necessity for careful installation of the carbon lining and accessories, nor does it do away with the requirement for good judgment in apparently minor details of operation.

Operation of blast furnaces under pressure continued throughout the year reinforcing previous results. Sufficient experience has now been assembled to substantiate the claims of the proponents that the increased pressure, obtained by throttling the top gases, makes possible much higher wind rates, but with much lower velocities of the gases through the furnace. The results are greater production of iron with less coke consumption and a decrease in the amount of flue dust, along with steadier operation. The year closed with eight stacks equipped, or about to be equipped, for pressure blowing.

Another method of approach to the same problem has been the careful sizing of materials going to make up the burden in the blast furnace. The method involves the separation of the coarse lumps from finer particles. Only coarse material over a certain size goes into the burden, the rejected fines being diverted to other furnaces after being sintered if necessary. Lack of any constriction of the gases while passing through the furnace seems to make for better results in production and smoother operation than with unsized materials in the burden.

Blast furnace linings during the year continued the trend, generally, toward the higher fired-brick special fire clay taken up to Cone 18. Several stack linings were of the Missouri type, higher fired brick. Some attention was paid to electrocast brick for abrasion resistance in the top of the furnace, by replacing the stock-line armor in the top of the stack.

The work of previous years culminated in the announcement, during open discussions in 1948, that augmenting the oxygen content, and lowering the nitrogen content of the wind blown through the furnace would give increased production, richer top gases, and a saving in the consumption of coke. The principle involved is that the replacement of the atmospheric nitrogen, which, being 4/5 of the wind blown, not only tends to stifle the process of combustion, but also compounds the error by causing excessive loss of heat through the escape of the inert portion of the effluent gases. The current work of investigation is on a production scale completely removed from the comparatively small-scale experimental work done several years ago by different European investigators. Further progress on this phase awaits the availability of "bulk" low-purity oxygen. It is interesting to note the European opinion on this point. For instance, the French technologists point out that the cost of the equipment necessary to handle the oxygen around a blast furnace yields only a slight improvement in the calorific output and a negligible savings in coke per ton of iron.

The use of refractory concrete materials has found economic application around the coke ovens. Refractory concrete has made considerable progress in the last few years because of shortage and time required to obtain various sizes and shapes of burnt material from the manufacturers. We know that refractory concrete has been used in the doors of coke ovens for some time. Gun blocks, jams, and other coke-oven shapes have been precast and used in repair work in coke ovens. Likewise it has been used successfully in soaking pits, both side walls and covers, heating furnaces as well as open-hearth flues, and similar applications.

### open hearth

New open-hearth installations in 1948 were one at the Fontana, Calif., plant of Kaiser & Co., one at the Otis works of the Jones & Laughlin Steel Corp., two at the Dearborn plant of the Ford Motor Co., and two at the Birdsboro plant of the Penn-Ohio Steel Corp. These installations meant a net gain of some 400,000 tons in annual open-hearth capacity.

The main open-hearth development of the year was the intensive work done on the use of oxygen to improve combustion as well as to speed up the refinement process. To take care of the large requirements of oxygen several plants installed equipment to supply the necessary amounts of bulk or low-purity oxygen. Other plants have been equipped to handle oxygen in tanks from which it is piped around the plant.

Oxygen for open-hearth combustion purposes, during 1948, was used chiefly for increasing the sharpness of the combustion flame, thereby reducing the scrap melting time and increasing the firing rates of production. It also has enhanced the properties of those fuels with lower calorific values. The results have been favorable.

In the reduction of carbon and silicon by open-hearth bath lancing, the results have ben mixed in those cases involving the higher ranges of these two elements. The major difficulties arise from the troublesome dust, heavy red fumes, and shorter life of the refractories. The dust and fume problem has led to the installation of wet-washing and precipitating apparatuses which have been accomplishing good results.

However, it must be pointed out that the use of oxygen for decarburization of open-hearth baths has been productive of good results in the lower-carbon ranges, especially in connection with those heats intended to be of low-carbon content.

The use of oxygen seems to have the desirable advantage of raising the temperature of the bath. Also the agitation of the bath by the use of oxygen seems to supplement that brought about by the lime boil.

Likewise, the melting of scrap, especially of the lighter varieties, has been speeded up by the use of oxygen due to the possibilities of setting up localized heating conditions, by the manipulation of the oxygen lance.

All these uses and applications have set up the requirement that the open-hearth furnaces using oxygen must be equipped with a cheap and simplified means of handling the oxygen expeditiously through the shop. Likewise the flow of traffic must be so arranged that there is a minimum of interference at the particular furnaces using oxygen.

These full scale production tests in the open hearth show positive indications that the use of oxygen is past the experimental stage and will win general, while not universal, acceptance in the larger shops.

Increased attention has been paid to the silica brick used in open-hearth roofs, with special emphasis being paid to the rate of heating up a new installation. It has been established that a new open-hearth roof should have a gradual, continuous increase of heating, especially through the lower temperatures when there is a marked increase in the volume, due to a change in the crystalline make-up, of the bricks.

Considerable attention is now being paid to silica brick with a low amount of alumina, the content of which has been found to have an important bearing on the life of the open-hearth roof.

The use of basic brick in the open hearth became of increasing interest during the year. Some thirty furnaces are now equipped with basic-end construction. Some reports indicate that fuel consumption per ton of product in the basic-end furnaces is lower than that of silica-end furnaces. Among the reasons for this are: (1) quicker furnace repairs cut down the time required to reheat the furnaces to operating temperatures as well as the time required for repairs; and (2) the greater ease with which the slag pockets can be cleaned out after each repair, thus giving uniformity of good operating speeds throughout the different campaigns.

The all-basic furnaces, one at South Chicago and the other in Canada, are still under longtime operational tests under varied practices. While no accurate comparison can be made to a furnace operating under "normal" conditions it is hoped that, should improvements be evolved in materials and constructional details as rapidly as in the past few years, an all-basic furnace will be worked out with good production rates, decreased costs, and, finally, improved quality.

Open-hearth mixer linings have come in for their share of attention. Several installations have been made of mixer linings made from special high alumina content material (Sillimanite) with favorable results. In some cases the life of the mixer lining has been doubled.

New Bessemer plants were installed in 1948 as component parts to complement other processes rather than as producers of Bessemer steel as such. During the year there was interest in the possibilities of the Bessemer being aided by the use of oxygen to enrich the blast. Further development of this idea awaits availability of oxygen supplies.

Pyrometry came in for its share of attention during 1948, especially in connection with the ever-present desire for closer temperature readings of the molten bath in both electric furnaces and open hearths. Two schools of thought in the industry have been discussing the merits of their respective ideas. One school of thought uses the immersion pyrometer, not to eliminate the older methods of judging bath temperature, but as a check on the finer adjustments of the more exact temperature of the molten steel. The immersion types have given excellent correlation between the tapping and pouring temperatures, especially on the electric furnaces. The other school of thought follows the radiation pyrometer, especially on open-hearth furnaces. Each type, the immersion thermocouple and the radiation pyrometer, has its own merits and demerits, but both have been of help in reducing fuel costs, bottom delays, and the number of off heats. Most interesting of all has been the enthusiasm with which the operating personnel have taken up this new tool in the various plants in which it has been installed.

## direct casting

One of the most interesting developments to come to light during the year was the continuous casting of steel billets by a process which takes steel from the liquid phase to the semi-finished shape in a few comparatively simple operations. The sequence involves molten steel poured, through a tundish, into a water-cooled mold, the chilled billet passing through a vertical insulating sleeve, then through pinch rolls controlling the movement of the billet which is cut to desired length by an automatic torch. This development will be watched with interest to see if its progress parallels that of similar processes in the nonferrous fields.

## alloy steel

Alloy steels became of increasing importance in 1948, running close to ten per cent of the total ingot production. While such a percentage is lower than the wartime figure, it is much higher than the six per cent average of the prewar years. The tonnage of alloy steel produced during 1948 was fifteen per cent over the tonnage of 1947. It must be pointed out that the greater part of this increase was due to alloy steels produced in the open hearth.

An interesting fact is the accompanying rise in electric-furnace production which, during the latter months of the year, exceeded in percentage operation the rates of operation in the alloy open-hearth shops. The main reason behind such rates of operation can be attributed to increase in the demand for carbon steels from the electric furnaces due to unusual economic factors which were beyond the control of those concerned with the more technological aspects. Electric furnaces in steel foundries, in alloy steel plants, and even those in tool-steel plants, were swung over to the production of rimmed and semi-killed carbon steel for rolling into flat-rolled products.

During the year nine electric furnaces were installed or rehabilitated giving the annual electric furnace capacity an increase of 688,000 tons. Seven of these nine were of the larger 50 to 70-ton capacity which, combined with ample power and skilled operation, have been found to give good tonnage and production rates. The other two furnaces were 15-ton furnaces that were moved and rebuilt into 25-ton size. Considerable attention was paid to the possibilities of minimizing the charging time by the use of top charging, which seemed to be advantageous when necessary to use the poorer grades of scrap. The thirteen electric furnaces projected at the end of the year were more than at any time in the history of the art.

During the course of the year an apparent tightness in the supply of nickel caused some shifting of analyses, wherever possible, from the high-nickel steels to those carrying a lower nickel content. Likewise, the problem of residuals became somewhat more difficult to handle. These two tendencies made it necessary to swing some important requirements over to the nickel-chromium-molybdenum types. One of the interesting developments was the extent to which the 8600 series of analyses have established themselves in the steel-consuming areas. The severe trials of actual application have proven the merit of this series. The making of alloy steel heats has been helped and speeded up by the use of oxygen not only in the open hearth but also in the electric furnaces. This parallels the experience with carbon steels.

## stainless steels

Stainless steel production in 1948 continued the trend of recent years toward the low-carbon types. There was also an increase in the production of the higher-alloy types of stainless steels with high mechanical properties at elevated temperature. These steels with their heat-resistant characteristics presented a real difficulty to the operating metallurgists. Some production research was done on these special types toward the replacement of columbium by titanium. This was looking to the time when columbium might become less available.

The production and use of stainless-clad steel were also expanded during 1948. This increase is due to the enhanced metallurgical and physical properties of these composite metals.

One interesting development is the adaptation of stainless steel to roofing accessories. Quite a few producers are now prepared to make a complete line with eaves trough, downspouting, and the various attachments all made of stainless steel, which meets the requirements of such service not only in the ability to take complex forming and bending, but also in the desirable feature of longevity due to its corrosion-resistant properties.

Without going into repetitive details, it should be mentioned that the iron and steel industry is taking full advantage of the work done in the many sciences that can be applied to its problems. These various sciences, including that of statistical analysis, spectrographic as well as X-ray diffraction analysis, pyrometry, and radioactive isotopes are being used to keep to a minimum any possibility of guesswork in the assembling of the fundamental data so necessary to the soundness of important decisions.

# Coal Industry . . .

## . . . has good year; slackening demand closes marginal operations, others study production of better product at lower operating cost

Foreword by **CLAYTON G. BALL** • CHAIRMAN, COAL DIVISION, AIME

In the year 1948, more than ever before, the coal industry established itself on the threshold of a new and exciting future expansion. While production did not equal the wartime and peacetime peaks of 1944 and 1947, it was, in review, a good coal year. During the latter part of the year a combination of mild weather, record stock piling, and general business slackening reduced coal demand to the extent that marginal mines suspended operations, while mines remaining active found it necessary to renew their attention to producing better products at lower operating costs.

Prospects for securing substantial decreases in underground mining costs were materially enhanced by the unveiling of two different types of continuous mining machines, machines which replace the hitherto separate operations of cutting, drilling, blasting, and loading with one continuous process. It is not expected that introduction and delivery of these machines to existing mines will result in an immediate revolutionizing of mining procedures and costs. However, after the improved mining methods and techniques made possible by this new equipment are developed by careful engineering and intelligent trial, appreciable savings will undoubtedly result.

Partly through military considerations and partly in conformance with the immutable laws of supply and demand, the year of 1948 saw at least the beginning of a gradual decentralization of industry. On a regional

**A gradual decentralization** of industry, and the question of America's coal resources presented important problems during the past year.

basis, such decentralization has profound implications to the coal industry. Shifts in centers of consumption may curtail the output of an active coal-producing district unless, or until, lowered delivered costs or other forms of utilization are developed. Likewise, coal-producing areas hitherto remote from substantial markets may become revitalized by construction of new coal-using facilities and plants.

A most promising field for future new utilization of coal, incipient heralds of which became stronger and more numerous throughout 1948, is the synthesis of liquid fuels from coal. Included as part of the program for long-range military requirements, both government and private industry conducted preliminary investigations of potential synthesis plant locations where the many economic factors of raw coal supply, process and cooling water, disposal of waste, and transportation to markets might most efficiently be met. To produce one million barrels of oil per day, less than 20 per cent of the present consumption, nearly 200 million tons of coal would be required per year. The establishment of potential locations of mines to supply coal to thirty-four 30,000 barrel-per-day plants, this being the required number of what is considered as the most efficient size of plant, represents an acute problem in selecting favorable sites consistent with economic producing costs and with sufficient quantities of minable reserves.

During 1948 grave questions arose concerning the interpretation of previous estimates of our national coal reserves in terms of present mining methods and physical requirements. Pointing out that these previous estimates included vast amounts of reserves which today would be considered as worthless or no better than marginal, the Coal Division called for immediate re-examination and, together with the Coal Resources Committee of the National Bituminous Advisory Council, recommended a plan for a rapid reappraisal of bituminous coal resources to the U. S. Department of the Interior.

An important step in the conversion of coal to a synthetic liquid fuel was taken by Pittsburgh Consolidation Coal Co. in 1948 when it completed a coal-gasification pilot plant at Library, Pa., where the gasification process may be investigated under a variety of operating conditions to determine commercial designs and probable costs. This is but one example of the steadily expanding development and research in various phases of coal production and utilization which will be described in the following sections of this Annual Review.

With augmented combustion and heating services to consumers, with improved labor and public relations, and with increased awareness within itself not only of its fundamental importance to our economic structure but also of its social duty to the national community, the coal industry continues to direct its activities toward greater economy, higher efficiency, and complete industrial fulfillment.

# ANTHRACITE INDUSTRY . . . *equals '47 production, mines thinner seams, studies utilization*

By **H. A. DIERKS** • CHAIRMAN, ANTHRACITE MINING METHODS COMMITTEE, AIME

In the first nine months of 1948, the anthracite industry gave every indication that the production of 1947 would be exceeded by 1½ million tons. However, the warmest September to December period in the annals of Eastern seaboard weather cut off the demand to the extent that the estimated commercial production can be stated as 54,140,000 tons, exclusive of colliery fuel, thus only equalling the 1947 production. While final figures will not be available for some time, as this is written it is estimated that of the 54,140,000 tons, 33,140,000 came from underground mining operations, 12,000,000 from strippings, and 9,000,000 from washery and dredging operations.

With only estimated figures at hand, it is too early at this time to draw any conclusions as to the man-day production of the industry. The number of days worked and the number of employes has not varied to any great extent from the last few years.

Relative to safety, 1948, however, established a record with a new low mine-fatality rate for the anthracite industry. The official rate of .85 fatality per million man-hours, as published by the Pennsylvania State Bureau of Mines, continues a trend which shows a decline during the past eleven years. Operating companies, state and federal agencies are striving constantly for increased safety measures and safety consciousness on the part of the employes so as to continue this decline in fatalities in the mining industry.

Mining of thin veins, previously considered unminable, has increased the use of mechanized mining. The difficulty of procuring new equipment as well as general mining supplies, such as rails, ropes, pipes, sheet iron, and lumber, continues to retard more extensive use of mechanical mining and the extension of dust control.

Relations between labor and management were noticeably of a composed nature during 1948. A new wage agreement with the UMWA, signed July 3, and going into effect July 16, 1948, granted all workers a flat increase of $1 per day. The $100 vacation payment established in 1947 was made for the vacation period which was uniformly observed throughout the industry during the period of June 26 to July 5, inclusive. Contribution by operators to the Anthracite Health and Welfare Fund was increased from ten cents to twenty cents per ton of coal produced for use or for sale.

Effective July 16, anthracite prices were increased so as to compensate for the wage increases given throughout the industry. Retail prices were further affected by the actions of the Interstate Commerce Commission which granted the rail carriers a rate increase of 40 cents per net ton on anthracite and bituminous coal, and coke. This rate became effective in July 1948. As this article is being written, another tentative rate increase of 16 cents per net ton has been granted to the rail carriers by the ICC.

During the severe cold weather early in 1948, anthracite users were supplied plentifully throughout the competitive fuel shortage. To avert any shortage through the present winter months, anthracite users were advised to "fill-up" their bins early to be assured of warmth and comfort during the winter.

The "fill-up" campaign was successful as seen by a high demand for anthracite during the late summer months. This demand helped keep the summer production at tonnages higher than those of past years.

Dealers reported an encouraging acceptance of anthracite stokers and expect a greater demand in 1949. This, accompanied by the production of the new Anthratube, indicates an increasing market for anthracite. The demand for the Anthratube is high and producer's records show that over 1000 units are already in operation. It was through the efforts of the Anthracite Institute that the Anthratube was developed.

The Anthracite Institute is continuing research efforts to find varied uses for anthracite silt. Work has begun on a fluidized-bed process which produces fuel and synthetic gas from anthracite silt. Another project is that of pellitization, or the upgrading of fine sizes by extrusion under great pressure. Perfection of these processes will make use of the large stores of anthracite silt already above ground, estimated to be 100,000,000 tons, and the annually-produced supply of 6,000,000 tons.

The Sixth Annual Anthracite Conference was held May 6 to 7 at Lehigh University, Bethlehem, Pa. Outstanding papers presented at the meeting covered the production and utilization of anthracite, subjects of consequential interest to all phases of the entire anthracite industry.

Throughout 1948, which can be considered as a good year for the anthracite mining industry, the large producing companies continued in their efforts to improve their products as well as their operating efficiencies. Serious perennial problems continue to trouble these producers who look forward to high production in future years. The problem of dust control is receiving considerable attention throughout the entire industry.

Pumping costs increase concurrently with the progressive extraction of pillars, thus making pumping a major threat to the industry. The Bureau of Mines has recognized the seriousness of the drainage problems which beset the anthracite industry and has started on a comprehensive project to study the problems involved and then formulate a course of action. Funds for this project were appropriated by Congress for the fiscal year 1948 and it is expected that similar funds will be appropriated for succeeding years until the project can be brought to a fruitful conclusion. Recognizing the necessity of using the knowledge already gained by the industry at large, various companies have released key men to this project in order to co-operate to the fullest extent with the Bureau of Mines.

# BITUMINOUS MINERS . . . *benefit by co-operation with machinery manufacturers, preparation men, researchers, with record production per man employed in 1948*

By **J. W. WOOMER** • CHAIRMAN, BITUMINOUS MINING METHODS COMMITTEE, AIME

American bituminous deep mines in 1948, faced with the 1947 record of the highest wage in 158 industries and with high standards of safety and social demands, but paced by the progress of coal chemistry and an apparent goal of increased markets, have moved forward in 1948. Although harassed by slow machinery deliveries, slow construction work, and by coal-car shortage, yet it appears that the deep mines will have contributed their share toward improving the total industry's performance by bettering its 1946 record average of 5.43 tons per man employed.

This tonnage improvement is noteworthy in that it has been accomplished with a good safety record and with expanded, yet realistic, ideals of coal conservation and the necessity for laying the ground work for future lower cost per ton. During the year its financial, engineering, and operating men have been busy either increasing their amount of mechanical face equipment and its performance or, by necessity, upgrading their "back-up" installations such as power, haulage, and preparation, to enable them to go another step forward toward decreased face costs. The financial demands for this program have tended to accelerate the movement of the industry during this and recent years toward fewer mines and these producing greater annual tonnages.

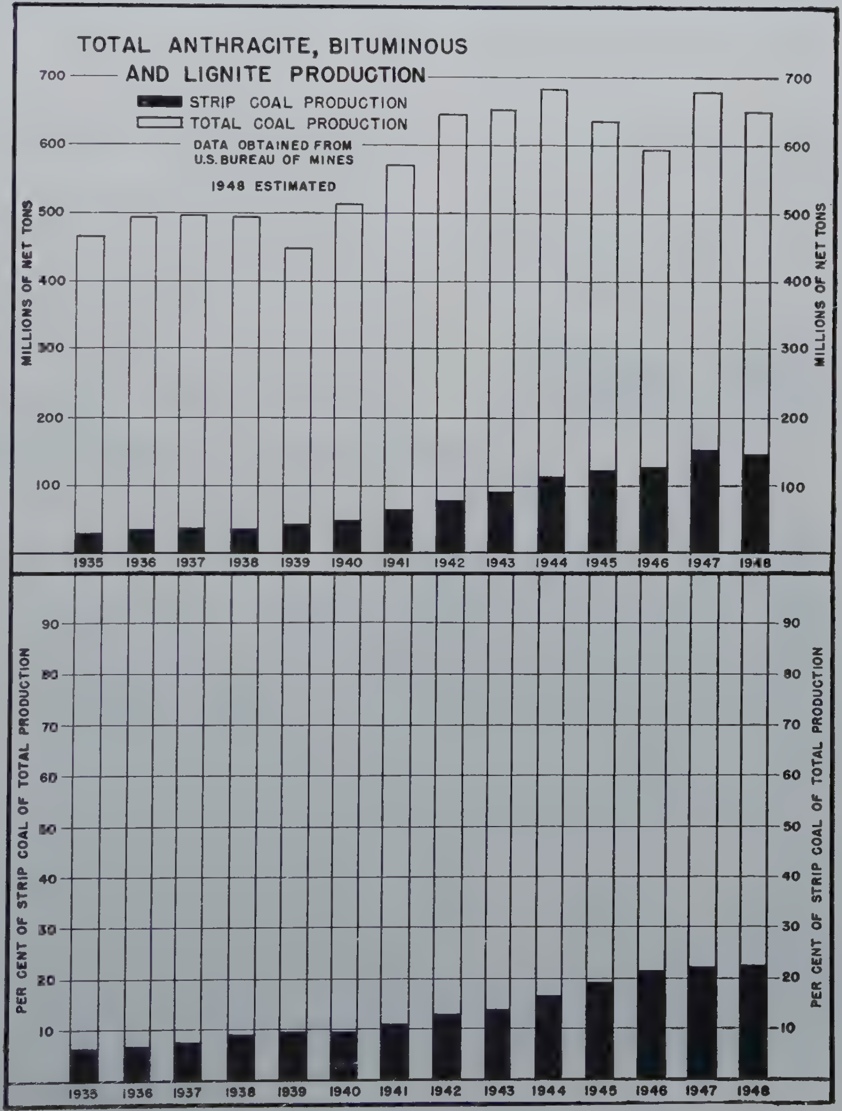
Continued improvement in mine cars and rubber-tired haulage equipment, as service equipment for face loading machines, has kept pace with the large number of changes in face to tipple arrangements during the year. Most significant is the movement toward partial or complete belt haulage even in the thicker-seam mines. This trend has been accelerated by the almost universal planning for high production crew units or concentration of medium sized production units on one haulage arrangement. The year has developed many ingenious devices to control the loading of tandem belt conveyors and the protection of the conveyors and the mines from mechanical or fire damage at these points. In 1948 there was almost universal adoption of the use of elaborate automatic electrical mine-sectionalizing equipment and practically a standardized application of circuit-control junction boxes for the several face-load-branch electrical circuits.

During the year many auxiliary types of equipment have been developed and added to installations, particularly in the field of rubber-tired haulage. Man-trip cars, material cars, jeeps to aid mechanics and officials in traveling underground, and various rubber-tired utility cars for welders, rockdusters, etc., are now common equipment in the mines.

The year has seen the development and large-scale application of track and rubber-tired man-trip cars and mobile hospital and fire-fighting equipment for underground emergencies.

For the production face, self-propelled timbering machines, self-propelled compressors for breaking coal with air, and self-propelled drilling machines have been improved even over their wide development and application during 1947.

Outstanding, however, during the year was the formal unveiling of the long-looked-for continuous mining machines. First came the Colmol. This is a multiple auger-type boring machine on caterpillars. This machine, which does not as yet have a universal joint between its traction body and its cutting head, has cut and loaded large tonnages per minute in test runs without other cutting or blasting machines. Next came the Joy Continuous Miner which had been in development for several years. This machine utilizes a multiple cutting chain head with conventional bits connected to the traction and conveying carriage with a universal joint which permits the cutting and loading of a place much wider than the body of the machine. This universal head allows the cutting head to follow the undulations of a coal seam because the lateral and vertical movement in front of the universal joint is independent of the traction caterpillars. This manufacturer claims 25 machines in coal production at this time under all kinds of seam conditions and states their factory is tooled to produce at least that many per month hereafter. The year also saw new financial, production, and engineering life given to the well-known McKinley Entry Driver, which is also a continuous miner. The actual availability of continuous miners is, without a doubt, the start of a new era in



Total anthracite, bituminous, and lignite production from 1935 to 1948.

**Reforestation** of stripped areas and the revegetation of spoil banks achieve results like the attractive view shown here, and are given careful attention by coal operators.

coal production. Surely there are transportation, dust, coal size, labor rate, ventilation, tool steel, and even mining system problems to be met before it will be universally applied, but the first development stage of the dream seems to be behind the industry.

It seems, therefore, that standing at the beginning of 1949, the industry's bituminous mining men, in cooperation with their old friend the machinery manufacturers, preparation men, and coal research technologists, can look their competitors squarely in the face and can guarantee America an economical fuel in the future.

# STRIP MINES . . . *produce 22.2 per cent of coal output; equipment manufacturers aid industry*

By **R. H. SWALLOW** • CHAIRMAN, STRIP METHODS SUBCOMMITTEE, AIME

Total combined production of anthracite, bituminous, and lignite strip coal in the United States for 1948 has again shown a percentage increase. Of the total 1948 estimated production of 648,000,000 tons, strip mines accounted for 144,000,000 or 22.2 per cent of the entire amount, as indicated in the chart on page 115. This occurred in spite of a slight recession in the coal market in the later part of the year. No doubt the upward trend will reverse somewhat in 1949, as quite a number of small operations are even now closing down because of lack of demand caused by unsatisfactory coal preparation facilities. Many of the smaller strip operators were primarily engaged in earth moving work or road contracting, and only entered strip mining because of the abnormally heavy demand for coal during the past several years. Many of them will return to their original businesses.

Improvement in shovels and draglines has been primarily in the use of more powerful engines and the adoption of a larger, redesigned alloy buckets. Machine designs have remained basically the same because manufacturers have been producing them in quantity. However, several improvements have been made, in other stripping tools, including the building of a second-wheel excavator of greater capacity and reach, and additional uses for the tower excavator. As the stripping phase is the primary operation in open-pit mining, new ideas are being studied to utilize present equipment in various schemes for removing over-burden more efficiently and to greater depths.

Experiments and tests are being made continuously to improve drilling equipment for overburden preparation. The latest drill to be tested, particularly for hard limestone, has been the multiple - mounted air jackhammers, drilling vertically. Various types, shapes, and designs of drill bits have been given careful attention.

Means of attaining increased efficiency in blasting the high-wall banks have been considered, both with fixed and liquid oxygen explosives. Use of the latter product has shown an increase, particularly at large operations with tenacious rock formations. With the increase in the size of drill holes it has been necessary to develop larger blasting cartridges.

During the war, improvement in truck design for coal haulage was at a standstill, but since that time the trend has been toward units with larger pay-load capacity. To a great extent this has been made possible by the development of larger tire sizes. One quite recent application, in a dragline pit, is the use of 38-ton pay-load tractor-trailer units on single tires rather than duals. This haulage is on fire clay and it is felt that better roadability is gained by this method on soft ground. This is an adaptation learned from contractors hauling dirt over poor roads in construction work.

With the use of bigger haulage units, it was necessary to improve roads, mainly in the thickness and amount of ballast used. Tractors, graders, and road maintainers are needed to keep these roads in good condition to reduce repair costs on the haulage equipment.

Coal preparation since World War II has required careful consideration and will continue to do so as the trend from a seller's to a buyer's market progresses. Operators with efficient cleaning plants will secure the consumer business. Quite a number of new preparation plants as well as additions to existing plants, have been built during the past year. A great deal of research is being carried on in the development of heavy-media processes; tests in the use of the Cyclone for fine-coal separation continue, and various experiments on new types of heat dryers are being made. During the past year, the number of oil treating equipment plants for dedusting stoker coals has surged.

Proper cleaning, preparing, and drying of coal is only possible through the close co-operation of efficient laboratory control and plant operation. More laboratory facilities and personnel have been provided to conduct this work.

During the past year, general improvements have been made in the facilities for maintenance. Many repair and electrical shops have been enlarged and new equipment secured. During the war, drill presses, lathes, shapers, grinders, etc., were impossible to secure and have only recently become available. Wash houses, offices, and miscellaneous buildings have been improved. One new plant made use of color dynamic engineering in the painting of all buildings, plant, and equipment, including dragline and loading shovel.

Prospecting is important for those companies expecting to remain active in the future. In the past, most strip areas were discovered in the vicinity of daylight outcrops, but as these obvious locations were quickly acquired, it has now become apparent that geologic study and intelligent prospecting must be carried out to find new areas within recoverable stripping limits. As a result, the past year has seen extensive and competitive activity towards the acquiring of additional strip-coal reserves. With stripping tools of greater speed and capacity, fields of greater depth and thinner coal have now become areas of open-pit reserves. Ten to fifteen years ago, tracts of this nature would not have been considered economically attractive.

Since open-pit mining requires careful consideration of all surface land conditions, topographic contour maps are essential to intelligent engineering, planning, and layout. In the past year or so, a new device has become available to the industry; contour maps of excellent accuracy are obtained by means of aerial photography. This infant method was given considerable impetus during World War II, and now gives the strip miner maps of greater detail and accuracy in less time and at lower cost than the conventional methods of stadia or plane table.

Strip-land reclamation has received careful attention during the past year, particularly from the state strip-mine associations, government conservation groups, and the mining companies themselves. The hiring of foresters, conservationists, and agriculturalists, who have devoted their efforts toward the revegetation of spoil banks, is an important step toward efficiency in land utilization. This is not only true for stripped-over areas, but also for lands acquired and held as reserves. The planting of forests, the seeding of large areas with legumes and grasses by airplane, the laying out of orchards and vineyards, the stocking of ponds and reservoirs with fish, and the development of facilities for raising cattle are some of the important steps that have been taken to assure the future use of land once thought to be of little value. As the slogan of one state conservation association indicates, strip mining is "harvesting one crop, providing another."

The strip-mining coal industry of this country is making studies to assure continued progress in the future by industrial experimentation and development of more efficient operating methods and by studious and conscientious efforts in research and long-range planning.

**Larger tires** make possible the 38-ton pay load of this Euclid truck which is being loaded by a Marion 6-cu yd coal shovel.

# COAL PREPARATION . . . *men concentrate on large-tonnage cleaning plants, treatment of finer sizes, drying processes in 1948*

By **T. W. GUY, D. H. DAVIS, J. S. JOHNSON** • CHAIRMEN, COMMITTEE ON COAL PREPARATION, AIME

A survey of plants for which contracts were let in 1948 further confirms the trend toward increased mechanical preparation throughout the bituminous field. Interest in heavy media continues at a high pitch although contracts let were not a major factor in the year's contracted tonnage; apparently further operating information is awaited from the large tonnage plants of the captive operators. One plant using magnetite and another using sand, both units making separations at two different gravities, will soon be in operation, and should furnish valuable information in 1949. Acceptance of the jig as a satisfactory cleaning device is confirmed by the fact that the majority of plants contracted for are jig plants and their combined tonnage is over half of the total contract tonnage. A feature apparently contributing to the increase of jig tonnage is undoubtedly the so-called package plant; these units generally of about 75-ton capacity have wide appeal particularly for the smaller operator who wishes to improve products in the 5 to ¾-in. size range without large capital expenditure. The majority of jig contracts call for cleaning of 5, 6, or 7-in. down to 0-in. size coal, in tonnages of 60 to 600 tons per hour.

The Chance sand-flotation system continues to be frequently chosen for cleaning coarse coal at sizes as large as 8 in. and extending down to ⅛ in. Often a size range of 6 to ⅜ in. is treated in one cone and at other plants the coal is split into sizes such as 8 by 2 and 2 by ¼ in., each size being cleaned separately in an individual cone.

The hydroseparator has registered the next largest contract tonnage. In most cases, these units will be cleaning grades between 5 and ⅜ in. and usually maintain a size ratio in the feed of 3 or 4 to 1. In several contracts hydrotators and hydrotator classifiers have been included to clean the ⅜-in. to 0-size portion of the raw coal.

Air tables have been accepted to clean ⅜ by 0-size coal at a number of locations but no mention has been made of predrying the coal at these plants. For certain coals, the combination of predrying and air cleaning may be worth investigation.

For wet cleaning of fine coal the concentrating table has been most widely selected. The table is a simple unit to install and operate, and this accounts for its wide use. Many high capacity fine coal plants have selected tables to clean fine coal. In addition to being used as a primary-cleaning device, the wet table is also being used to recover fine coal from the reject of other separating devices operating with a feed of wider size range. Several large table installations with unusual features are now undergoing adjustment runs. In one large plant the ¼-in. by 0-size raw coal is taken from the primary shaker directly to the table-feed distributors thus eliminating any settling or classifying devices ahead of the tables. Elimination of this equipment should mean a substantial saving in plant cost.

Increased interest is being shown in the possibilities of using oil flotation for cleaning bituminous coal slurries, but actual installations in the bituminous field are few, and tonnage-wise are of little importance. In the Birmingham district a lot of experimenting is being done in an effort to improve present methods for cleaning and dewatering the sludge and slurry sizes at plants producing coking coal and to devise means for obtaining a higher yield of coking coal in proportion to steam coal from the bony Mary Lee seam. One installation treats about 200 tons per day of sludge underflow from dewatering screens by the kerosene-flotation process. It is as yet too early to appraise the performance of this plant from an economics standpoint.

Centrifugal dryers of both the solid-bowl and screen types are being installed in new plants and experience gained in the next six months with these units, operating under widely varying conditions, will be interesting. Results obtained by one operator using the solid-bowl centrifuge as a classifier through introducing large quantities of fresh water in the feed, has influenced them in the design of a new plant. In a number of plants the screen-type dryer has been used to classify settling-cone underflow by washing fine material through the screen and reclaiming a substantial amount of merchantable coal formerly wasted. The high cost of operating centrifugal drying units, coupled with severe degradation, have caused several operators to consider reducing the top size of coal handled by these units, thus reducing the number of centrifuges in favor of thermal-drying equipment, and also reducing the load on the water clarification system. A factor influencing this is the need for heat-dried stoker coal under ¾-in. size.

The cyclone thickener has undergone extensive tests but has not been widely accepted. One plant has made this device a permanent part of its water clarification system. At least one manufacturer is conducting tests on small diameter units mounted in parallel in an operating plant; these tests should help answer a number of questions, particularly those pertaining to maintenance. Where water clarification is critical the rake-type thickener and vacuum filter are being relied upon.

Thermal drying is gaining in popularity with the realization that excess moisture is in most instances equally, and in many cases more, objectionable than excess ash. Screen dryers are well established and flash dryers are rapidly becoming accepted as reliable operating units. In at least one recent large installation a bag-type collector has been included in the circuit and should serve to make this unit even more acceptable.

The consumers' demand for improved quality along with the increase in mechanical loading should further accelerate coal preparation activity. Some producers of marginal quality coal have fallen by the wayside while others may soon follow; to some of those, mechanical preparation would have meant continued profitable operation.

In the anthracite field there were additional installations for the recovery of the extreme fine sizes of anthracite, also the installation of a heat-drying plant and one or more dense-media plants were under construction which will use magnetite.

# UTILIZATION . . . *of anthracite and bituminous held steady at a high level in '48; latter looks for expansion in future*

By **CARROLL F. HARDY** and **E. E. FINN** • CHAIRMEN, COAL UTILIZATION—FUEL COMMITTEE, AIME

Sustained high level of industrial activity in 1948, with consequent demands for coal in both the industrial plants and the public utilities, continued to confound the prophets of industrial decline.

The production of bituminous coal, which broke all-time records in 1947, remained at a high level in 1948, and in the last quarter balanced the demand. Some of the marginal operations, primarily small strip mines, were closed down and thus the average over-all quality of the coal increased.

The electric utility industry continued to make the greatest expansion in coal usage. The amount used was over 100 million tons, thus equalling, or slightly exceeding, the amount of coal used by the railroads for the first time. All prophets are unanimous in expecting this growth to continue and to increase in tempo for at least the next ten years. The Edison Electric Institute expects coal consumption in the electric industry to reach about 146 million tons annually in 1960.

The growth of population has increased the demand for coal for domestic and commercial use and will increase it in the future. The program for synthetic oil and gas from coal is moving apace, and while this is not a factor in the present consumption, and probably will not be in 1949, the activity in this field presages the growing market in the future.

Although the trend toward Dieselization has made inroads in the railroad coal picture, the trend toward double-screened coal for locomotives became more pronounced in 1948. The consequent improvement in operation was remarkable, and it is likely that this long overdue change in fuel-buying habits will make the steam locomotive a more attractive source of power of the railroads. And even though the trend toward Dieselization has not slowed down, the fact remains that steam locomotives will be needed by the railroads for many years to come.

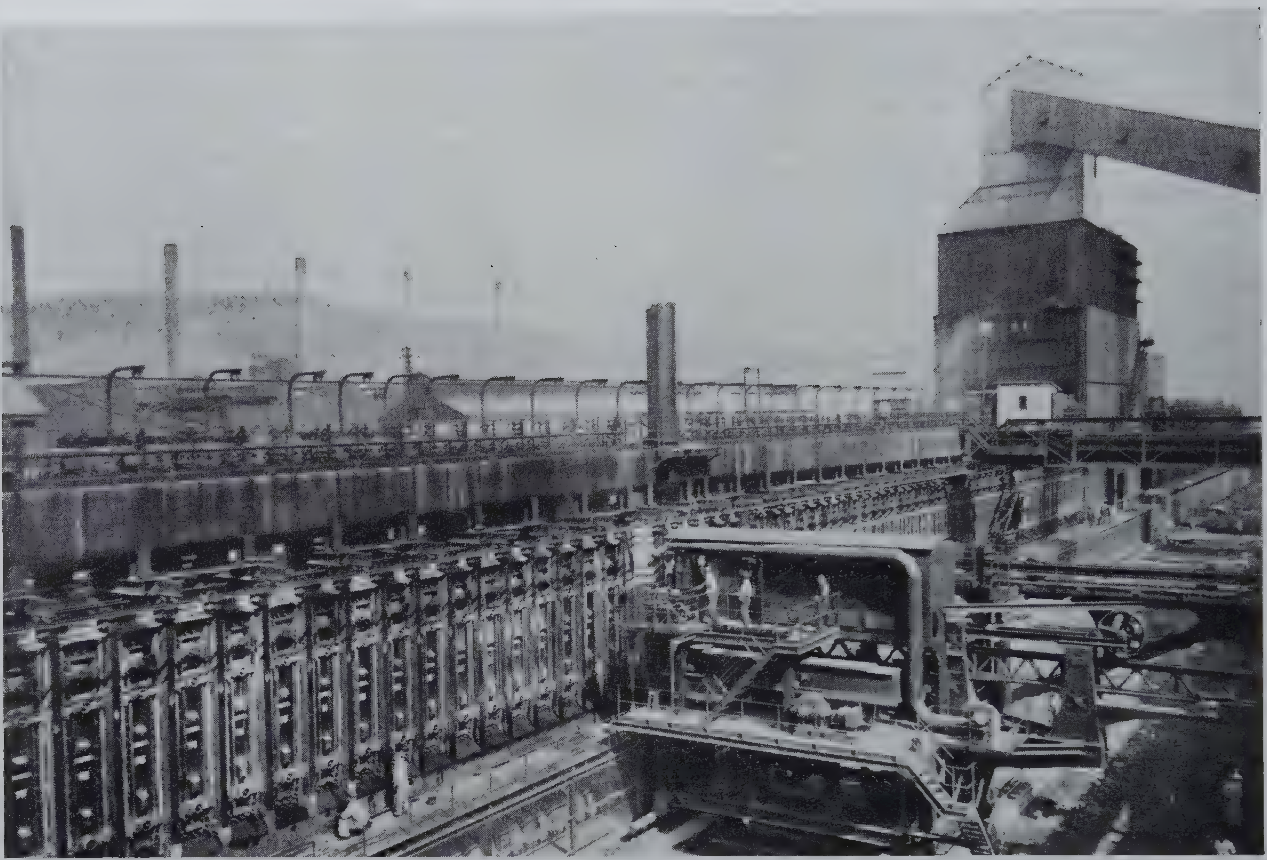
The tremendous expansion of industries in the South and Southeast has brought on greatly increased demands for coal in those areas. The balancing of production and demand, and the return to some extent of a buyers' market, has brought on new challenges and opportunities in fuel utilization.

There is a great and growing need for engineers in the coal industry. Increased mechanization, which includes the continuous mining machine, has brought on a new need for both mining and mechanical engineers in the production end.

In the field of utilization, the great need for trained men who are able to fit coals to the plants and to sell coal on a heating-value basis is so great that there is probably more opportunity in this field than in any other. Everything points to a continued high level of production and improvement in the utilization of coal in 1949.

Commercial production of anthracite for 1948 was practically the same as for 1947. However, the production in 1948 was adversely affected by several factors such as shortage of railroad cars and the record-breaking warm weather in the fall. This latter condition resulted in some sizes being in long supply with consequent reduced working time in the closing weeks of the year. The overseas export movement during 1948 was only 50 per cent of that during 1947.

There was a sizable increase in the sale of anthracite stokers during 1948 and manufacturers are confident that the impetus to sales in 1948 will lead to further gains in stoker sales for 1949. Over 1000 Anthratubes are in operation. Delivery of industrial stokers is still slow, requiring from 3 months to a year after ordering.



**A new battery** of 106 Koppers-Becker ovens at the Jones & Laughlin Aliquippa plant.

# COKE INDUSTRY . . . *expanding to keep up with large demand but handicapped by poorer quality coals*

By **JOSEPH D. DAVIS** • CHAIRMAN, COAL UTILIZATION—CARBONIZATION COMMITTEE, AIME

Increased demand for steel since the war and the resultant increase in steel plant capacity has called for greatly increased supplies of furnace coke. Construction of new coke plants is being rushed and old plants are being rehabilitated. In this respect the status of the industry is about the same as it was for the previous year. The $70,000,000 expansion program of the Jones & Laughlin Steel Corp. illustrates this activity throughout the industry; in this connection, a 106-oven battery of coke ovens was put in service at the Aliquippa plant during the year. Improvement in the design and operation of coke ovens has kept pace with the increase in capacity being built, and higher efficiency has been attained; in modern oven design the main objectives sought are increased capacity, uniformity of heating, and reduction, by automatic devices, of labor required.

The exact capacity of ovens placed in service during 1948 is not available at present. However, it is known that 421 new Koppers-Becker ovens having a capacity of 3,654,300 tons annually and 74 Wilputte ovens were put in operation. Rehabilitation of old ovens during the year will add 1,800,000 tons to annual capacity.

One important requisite to smooth, efficient operation of a coke plant is uniform grade and coking characteristics of the coal supply. During the war the normal sources of supply were disrupted owing to heavy demands and many plants were forced to use a variety of coals with which they were unfamiliar, resulting in production of inferior coke and loss of efficiency. It would appear that the demand for first-quality coking coal continues unabated in the postwar period and that the supply of premium, easily minable coking coal is becoming depleted. A general deterioration in the grade (higher ash and sulphur contents) of coking coal has been noticed for previous years, and Bureau of Mines' survey estimates for the year just passed indicate that this trend is continuing. The total quantity of furnace coke produced, increased somewhat more than 3 per cent. The amount of coke consumed

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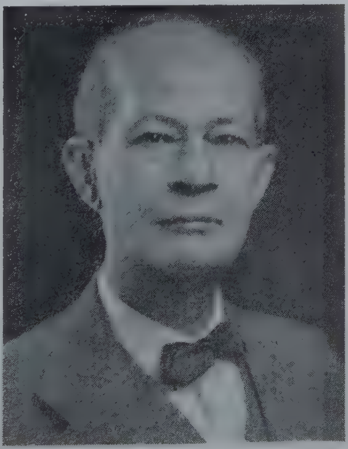
**The new "Disco" plant** in Pittsburgh, capable of producing 1000 tons of coal per day.

per ton of iron produced has increased by about 1.5 per cent. Recent estimates based on the experience of a large steel company show that, for each 1 per cent increase in the ash content of the coal, there is a loss of 1.9 per cent in iron production and an increased cost of production per ton of iron of 17 cents.

The situation as regards coking coals being as indicated above, it is pertinent to discuss briefly what is being done about it. Congress, in full realization of the importance of the problem, has provided for investigation of our bituminous coal reserves and for study of the coking coals in particular. An appropriation for the fiscal year 1949 has been made available to be used by the Bureau of Mines in determining the estimated minable coking-coal reserves in the United States as of Jan. 1, 1948. The program adopted includes: (1) determining the amount of minable coking coal in reserve; (2) determining washability; and (3) studying coking and blending properties. This program is now well under way. In tests for coking quality, low-volatile coking coals are being given first consideration; blending tests are being made of each new coal submitted, using a high-volatile coal whose industrial coking properties are well-known as standard. The behavior of the high-volatile standard with a low-volatile coal esteemed by industry for blending is also known. Blending tests using 20 and 30 per cent of the low-volatile are being used following a procedure established by the Bureau of Mines. Some ten low-volatile coals whose blending properties are not well known in the industry have been tested to date. Expanding properties of the coals and blends are also being determined, and the effect of oxidation will be determined when there is a question of storing properties.



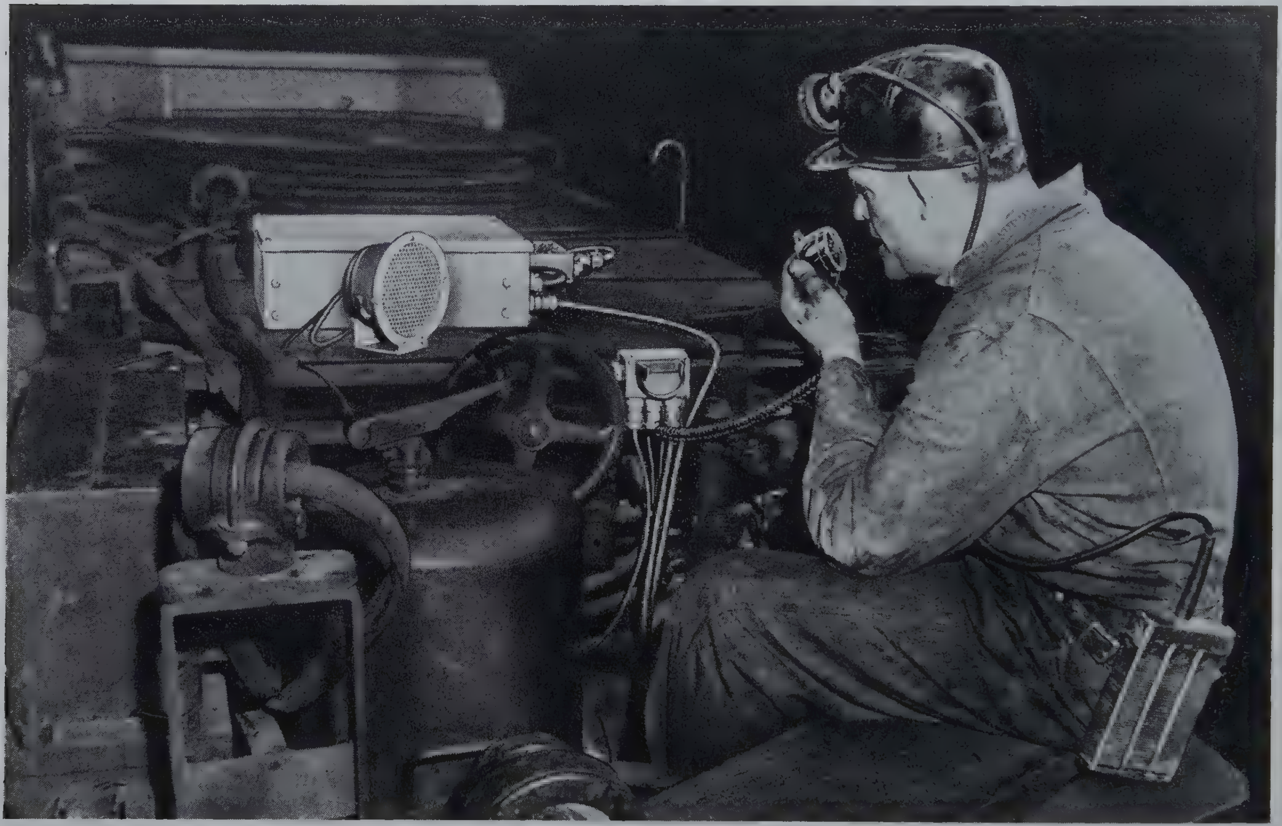
Joseph D. Davis

In addition to these government studies, technical societies and private organizations are investigating the quality of coking coal now available and its effect on steel production. The Iron and Steel Institute, in co-operation with the American Coke and Chemicals Institute, is sponsoring research on the quality of coke being produced and its effect on blast-furnace operation. One of the main objectives of this work is determination of sampling and test procedures that will adequately identify essential coke properties. It is planned to correlate results of tests on the coke with its iron-smelting properties in the blast furnace.

The outstanding work initiated by Gardner and his associates for Inland Steel in 1944 on the effect of coke quality on blast-furnace-iron tonnage is being continued. In this work the effect of variations in pilot-plant and oven coke, as measured by tests of coke quality by present standards on the amount and quality of iron produced by the blast furnace, is being determined. Within the range of variation of the cokes used, corresponding variations in blast-furnace performance are being found. Those planning these tests are in a particularly advantageous position, because they control not only operation of the coke ovens but also that of the blast furnaces. The Illinois Geological Survey is continuing the work initiated during the war on the coking properties of Illinois coals. This work is showing to what extent Illinois coals can be substituted for eastern coals in the manufacture of furnace coke and thereby increasing our available coking-coal reserves. The Koppers Co. is actively studying the expanding properties of coals and blends and the correlation of plastic with coking properties in the laboratory at Kearny, N. J. The Russell movable-wall oven is being used for determining expansion, and at the same time it gives a good idea of the quality of the coke. This oven has been widely adopted by the steel companies, and the Bureau of Mines uses a similar oven for the same purpose.

A research recently reported to the Institute on the use of radioactive sulphur in the form of pyrites for tracing the distribution of forms of sulphur in the carbonizing products obtained in a coke oven is of more than passing interest. It is shown, for example, that the bulk of the organic sulphur evolved in the gas is largely obtained in the early hours of the coking period.

The Lehigh Briquetting Co. at Dickinson, N. Dak., is continuing in operation, using the Lurgi process on lignite. The only low-temperature plant operating in the United States on bituminous coal and on a commercial scale is that of the Disco Co. near Pittsburgh. A new plant of 1000 tons per day capacity is under construction, and the company expects to place this plant in operation early in 1949. The Curran-Knowles ovens at West Frankfort, Ill., are continuing operation, but this is a medium rather than a low-temperature process. However, the coke is a smokeless fuel for which there is likely to be an increasing demand in the future.



**Communication equipment** like this makes it possible for the motorman to receive instructions from the despatcher while in motion, thus decreasing the chance for accidents.

# SAFETY . . . *in coal mines at best in 1948*

By **C. M. DONAHUE** • CHAIRMAN, SAFETY COMMITTEE, AIME

Application of the fundamental principles of safety to newer mining methods has made 1948 an outstanding year for the coal mining industry.

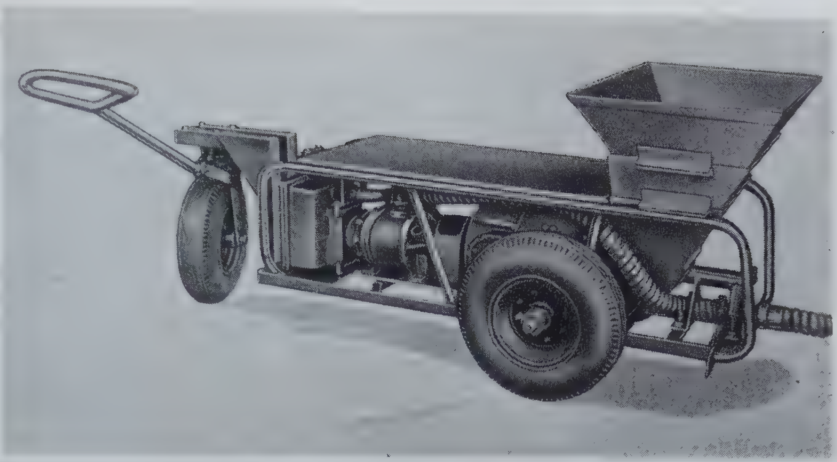
Anthracite mining, according to statistics released by the Pennsylvania Department of Mines, had the lowest fatality rate on record—.85 per million man hours. This is the lowest in the history of anthracite mining and a most noteworthy achievement. Although there was a total of 129 fatal accidents, it is impressive to observe that, in seven months during the year, the fatality rate was lower than the annual average and that for December the recorded fatality rate per million man hours was .56. Roof falls accounted for 80 of the 129 fatalities which is greater than 60 per cent of the total; blasts accounted for 7, cars for 14, and 28 were from other causes.

In the mining of bituminous coal, six major disasters, two of which were mine explosions, two roof-fall accidents, and one surface fire which suffocated five men underground, were the cause of 49 fatalities in a total of 870 reported by the United States Bureau of Mines. This represents 120 fatalities less than in 1947 when 990 occurred. For 1948 with a production of 594,000,000 tons, bituminous coal mining established its best experience in nonfatal accidents with a rate of 69.87 compared with 72.47 for the previous year when 630,624,000 tons were mined.

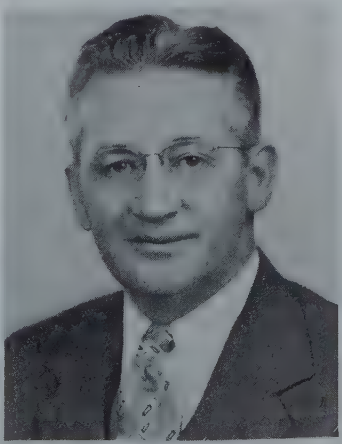
The accomplishments of the coal industry in its safety program, in part, may be attributed to changes in mining methods, to a more general adoption of explosion tested and permissible electrical equipment, and the availability of newer machines to improve mechanized mining techniques.

During 1948, programs to advance safety sponsored by operating companies, state and federal agencies, included vocational training, first aid and mine rescue contests, safety meetings on the job, special awards for improved safety records, plus greater emphasis on supervision and safety education. In addition, manufacturers are continuing to incorporate features which make for greater safety and efficiency in their designs of mining machinery.

Although considerable progress has been made in 1948, it is apparent that in the future more attention will be given to the reduction of roof-fall hazards, which regularly account for more than half of the fatalities chargeable to mining. Further, a more positive method of testing roof is desirable and means to do this are being studied by mining engineers as a guide to better roof control and support. Many companies are adopting new methods of roof support which experimental observations have shown to be effective. One type of roof support, which consists of securing steel rods in the roof strata, provides support for the exposed area near working faces and thus contributes to the safety of face workers. The bolting of suspension rods in roof strata will undoubtedly be more generally adopted in view of the safety advantages as well as the fact that more clearance is available in working places for mechanical equipment.


**Rock dust** can be kept within 40 ft of the face with small lightweight dusters like this.

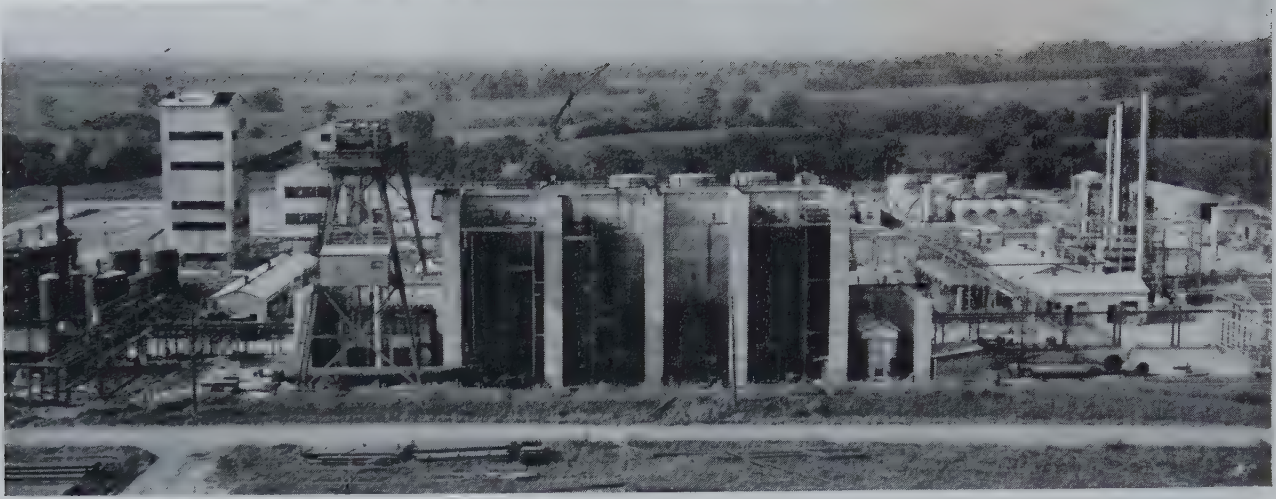
The application of rock dust was more effectively practiced during 1948 and it was evident from reports of few ignitions in coal mines that rock dust played an important role in confining explosions to small areas. To increase the protection afforded by rock dust, many mines are now following a planned program to keep rock dust to within 40 ft of the working faces, although it was previously considered good practice to dust within 80 ft of the faces. With the development of smaller lightweight portable rock-dust distributors, particularly of the high-pressure type designed for mounting on cutting machines, drill and timber trucks, it is possible to rock dust up to the working faces. These lighter-weight rock-dust distributors may be transported easily on conveyors or on rubber tired trucks into the working areas where their flexibility is increased by attachment of rock-dusting hose. These machines are so designed that rock dusting can be carried on in many places on shift as part of the mining cycle.


C. M. Donahue

A more general use of water on cutter bars has served to suppress coal dust at its source which makes for a clearer working atmosphere and adds to the safety and comfort of the workers.

Haulage safety has been improved by the more general use of heavier rail and better road beds, modern design in motors and cars, more general use of man-trip cars, automatic couplers, and dispatcher control of trips. With the development of modern communication equipment adaptable to mine motors, dispatcher's officers, and wayside locations, a more positive means of communication is provided which permits motormen in motion to be informed of any change in instructions necessary for the safe operation of his trip. With continued advancement of this type of communication and its application to hoisting shafts as well as to haulage transportation, there is ample reason to believe that accidents in these occupations will be reduced to a minimum with a resultant increase in efficiency.

Continued careful study of individual mining operations, the application of newer methods, and the more general use of approved equipment, particularly in mechanized mining areas and in transportation, plus adequate education and supervision will provide the foundation of co-operative effort to keep accidents to a minimum and safeguard men in their daily work underground.



**General view of stack,** Bureau of Mines coal hydrogenation demonstration plant, Louisiana, Mo.

# COAL RESEARCH . . . *continues expansion in 1948*

**By C. C. WRIGHT** • CHAIRMAN, COMMITTEE ON RESEARCH, AIME

A concrete expression of the expanding interest and activity in coal research is best seen in the new facilities for such work that were begun or completed during the year. Additions by the Bureau of Mines include the synthetic liquid fuels research laboratories at Bruceton, Pa., dedicated in May, the synthetic liquid fuels demonstration plants at Louisiana, Mo., which were nearing completion at the end of the year, the start of construction on the anthracite laboratory at Schulykill Haven, Pa., and the completion of designs and the procurement of a site for the lignite laboratory at Grand Forks, N. Dak. Research expansion by other organizations includes the addition of a new wing to the Natural Resources Building of the Illinois Geological Survey, the completion of the coal gasification pilot plant of the Pittsburgh Consolidation research laboratories at Library, Pa., the completion of a coal combustion laboratory and the beginning of construction on the New Mineral Sciences Building at The Pennsylvania State College; and the breaking of ground for new research facilities at the Institute of Gas Technology, Chicago, Ill.

### gasification

One of the primary phases of the synthetic liquid fuels program is the conversion of coal to synthesis gas. This problem, together with that of complete gasification to produce fuel gas, has occupied the attention of more organizations and investigators than any other single phase of coal research. A few of the major investigations include: (1) pilot-plant studies on the fluid-bed technique for the gasification of raw coal or char using air or oxygen and steam by the Pittsburgh Consolidation Coal Co., the Anthracite Institute and Hydrocarbon Research Inc.; (2) study of the various processes for the gasification of pulverized coal in suspension using highly superheated steam alone or enriched with oxygen, which include the vortex, cyclone, and Kopper's type units under development by the Bureau of Mines and the pressure gasification studies at the Institute of Gas Technology; (3) investigation of the fixed-bed processes which include the Lurgi-type pilot plant gasification studies of the Bureau of Mines, the work on water-gas reactions and producer-gas equipment at Battelle Memorial Institute and the slagging-producer studies at the Anthracite Institute; and (4) the underground gasification studies on a laboratory scale by the Bureau of Mines and the Anthracite Institute, and the preliminary work completed on the second large-scale underground gasification test by the Bureau of Mines and the Alabama Power Co.

Directly related to this program are the investigations on the kinetics of the gasification reactions, various phases of which are being actively studied at the Coal Research Laboratory of the Carnegie Institute of Technology, the Institute of Gas Technology, Massachusetts Institute of Technology, Pennsylvania State College, and the research division of Pittsburgh Consolidation.

Indirectly related to coal gasification problems are fundamental studies on the combustion of ash-containing materials at Battelle Memorial Institute, the Coal Research Laboratory, and Pennsylvania State College.

### combustion

Investigations on combustion and combustion equipment are continuing at a number of institutions and include: (1) the Anthracite Institute's investigations on hand-fired and stoker-fired domestic anthracite burning equipment and on the corrosion of stoker parts by freeze-proofing agents; (2) the B.C.R. coal-burning gas turbine, the application of the smokeless-stove principle to boilers and furnaces, the down-jet coal stove and the down-flow domestic stoker studies at the Battelle Memorial Institute; (3) the stoker-coal studies by the Illinois Geological Survey; (4) the application of suspended arches for improving combustion performance at The Pennsylvania State College; and (5) studies by the Bureau of Mines on the mechanism of furnace-wall tube corrosion.

### carbonization

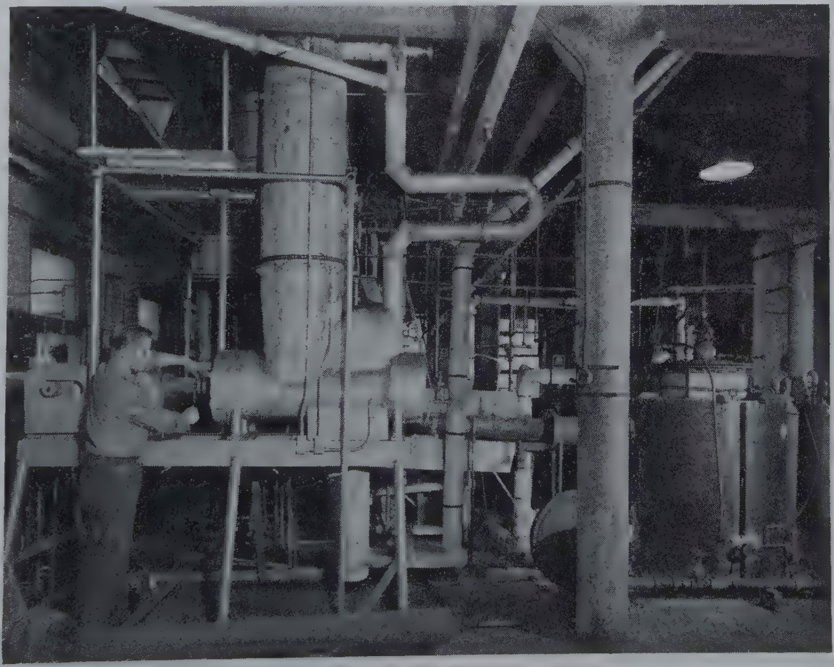
Research into both high- and low-temperature carbonization has been active for two principal reasons, the shortages of high-quality coking coals and the increased demand for smokeless fuels stimulated by renewed interest in smoke prevention ordinances. The research program of the Illinois Geological Survey on the use of Illinois coals in the production of metallurgical coke was actively pursued, and has been extended to investigations on the blending of inerts, especially char made from Illinois coals. The Institute of Gas Technology has completed a study on the influence of bulk density on coal expansion during carbonization and is investigating the influence of oven-heating rate upon coal expansion and gas evolution during coking. The fluidized-solids technique has been successfully applied by Pittsburgh Consolidation in the development of a continuous process for the carbonization of Pittsburgh-seam coal over the temperature range of 800 to 1500F with the production of a highly active char. The influence of blended inerts upon the coking or swelling pressure and upon the quality of commercially produced cokes is being investigated at Pennsylvania State College. The Bureau of Mines has continued its long-range basic program on the carbonizing and blending characteristics of coking coals by the addition of new coals to an already long list which has been examined.

### hydrogenation

Although less publicized than the Fischer-Tropsch type process, considerable work has been conducted and substantial progress made on the direct Bergius-type hydrogenation process for the production of synthetic liquid fuel. The 200- to 300-barrel-per-day demonstration plant of the Bureau of Mines at Louisiana, Mo., was virtually completed at the close of the year and represents the culmination of a vast amount of laboratory and engineering research. Improvements over European practice are expected to raise the over-all thermal efficiency to 45 or 50 per cent as compared with the 30 per cent achieved in the German plants. Bench- and pilot-scale work at Bruceton indicates promise of even greater increases in efficiency and decreases in processing costs through simplification of the means of securing or using the necessary hydrogen. Under appropriate conditions it has been found possible to substitute water gas for hydrogen. Of considerable interest is a new process in which part of the coal charge gives up its hydrogen to the remainder of the charge. Thus, in this Bureau of Mines development one portion of the coal is liquified, while another is converted to a coke or char which may be used as fuel.

### chemistry and nonfuel

There has been a gratifying increase of interest in fundamental and applied studies on coal and coal products not directly related to the three major uses of combustion, gasification, and carbonization. The investigation on the chemical and biological aspects of mine drainage has been continued at the University of West Virginia under the sponsorship of Bituminous Coal Research. This is leading to a better understanding of and prospects for the solution of an important problem. Extensive investigations on the chemical nature of the products obtained from the Fischer-Tropsch synthesis, on methods of converting synthesis gas to liquid products by the use of internally-cooled fixed-catalyst beds and oil-catalyst slurry techniques have been conducted by the Bureau of Mines. Research on the chemical constitution of coal, humic acids, and coal hydrogenation products has been conducted at the Coal Research Laboratory. The Illinois Geological Survey has continued researches on coal



**Flash pulverizer-cyclonizer** and cyclone gasification furnace employed by the Institute of Gas Technology in development of a continuous process for the gasification of pulverized coal suspended in a stream of steam, oxygen, and air.

constitution from the chemical, paleobotanical, and colloidal or ultrafine structure viewpoints and has initiated studies on improved methods of ultimate analysis. The chemical nature of humic acids and coal, the hydrogenolysis of pure compounds related in chemical structure to coal, and the use of "nitro humic" acids as an organic nitrogen fertilizer material have been studied at Pennsylvania State College. Methods for the recovery of chemical values from low-temperature tars are being investigated by Pittsburgh Consolidation. The New Jersey Zinc Co., Palmerton, Pa., has described and applied for patents on a process for converting the $SO_2$ in roaster gases to $CS_2$, using anthracite as the source of carbon.

### mining and preparation

In the general field of mining and preparation, research includes: (1) the extensive work of the Bureau of Mines on upgrading substandard coking coal by close gravity separation, the Kerosene-flotation combination process for cleaning and dewatering silt, the cyclone dewatering and cleaning of silt, the flash drying of subbituminous coals, the development of better methods for the open-pile storage of highly reactive lower-rank coals, and a comprehensive study of minable coking coal reserves; (2) investigations by several state surveys of minable coal reserves; and (3) investigations by the Mellon Institute and Pennsylvania State College on the cause, control, and elimination of gob-pile fires.

# COAL DIVISION . . . *sponsors two scholarships*

By **M. D. COOPER** • CHAIRMAN, COMMITTEE ON STUDENT INTEREST AND WELFARE, AIME

In the schools of mineral industries or the departments of mining engineering in the 33 colleges and universities in the United States granting degrees in mining, there was a general increase in the number of students preparing for work in the industry. Among them, there was greater interest in coal mining than formerly.

Closer contact between industry and education was brought about at the University of Illinois by the appointment of a group of leaders in coal mining to act as an advisory committee to the Department of Mining Engineering. This committee is actively engaged in planning greater facilities for teaching and will, no doubt, see to it that the graduates are given opportunity for employment. Similar committees are needed at other institutions.

The coal industry has developed scholarship plans rapidly during the year, so that there are now about one hundred in operation or soon to be started. These provide allowances of amounts ranging from $200 to $625 per year, generally with provision for employment during vacations. They are intended, not only as a means of developing trained men for the industry, but also of promoting good employer-employe relations, as some of the scholarships are awarded to the daughters of men employed by the companies.

The Coal Division has appointed two students to scholarships at $300 per year—one at Lehigh University and one at West Virginia University.

At Lehigh, Lewis W. Howells, Jr., is the recipient of the scholarship. Born in Norristown, Pa., in 1930, he travelled widely with his family in the United States, Canada, and Mexico; and, with his father, collected many mineral specimens. Graduating third in a class of 68 students at South Whitehall Township High School in 1947, he entered the university the same year and gained a place in the top fifth of his class. During the last summer, he took the required work in surveying, assisted with his home farm work, and was employed as truck driver at the shaft-sinking operation of the New Jersey Zinc Co. near Bethlehem. He is a member of the Howard Eckfeldt Mining and Geological Society, affiliated student society of AIME, and of Pershing Rifles, national honorary military society of ROTC.

Lewis W. Howells, Jr.

John C. Scott, Jr.

John C. Scott, Jr., is a student at West Virginia University, which he entered as a freshman in mining engineering in 1948. He was an honor roll student both in elementary and high schools, and was president of his class during his high school career, a member of student council, and valedictorian. In athletics, he won his letter in football and basketball. He served as a junior deacon in the Christian Church. His father is employed by The New River Co., Mount Hope, W. Va.

With young men, such as Howells and Scott, coming up from the high schools to the universities, it is hoped that the work of the Committee on Student Interest and Welfare may become increasingly effective in directing the attention of faculty and students in high schools to the opportunities in the coal industry, and that all members of the Division will consider it a privilege to aid in this work.

**Offshore drilling** operations in the Gulf of Mexico.

# The Petroleum Industry . . .

## . . . supplied increased demand for its products and made large additions to stocks and reserves.

**Foreword by I. W. ALCORN** • CHAIRMAN, PETROLEUM BRANCH, AIME

THE year 1948, critical during the early months from the standpoint of supply versus demand, demonstrated again the versatility of the oil industry in all departments. Contrary to many early postwar predictions, the demand for petroleum products has shown a marked increase each year since the war. Supplying a substantial increase in demand, and at the same time making large additions to stocks and underground reserves, was the industry's outstanding accomplishment of the past year.

An unusually large and rapid buildup of aboveground inventories occurred in the last quarter of 1948, when production and refining rates hit new all-time peaks. Consequently, stocks were pushed to levels where they were threatening to become excessive. Stocks of crude oil and three principal products, gasoline, distillate fuel oil, and residual fuel oil, increased 48.8 million barrels during the last three months of 1948 or at the enormous rate of 530,000 barrels daily. Therefore, their combined stocks at the year's end totaled 510½ million barrels, an increase of 94.8 million barrels over 1947's stocks.

As a result of this major trend in stocks, the industry in 1949 must return to its prewar policy of carefully regulating producing and refining rates to avoid further additions to storage. It is noteworthy that January and February 1949 production allowables were reduced by substantial amounts, notably in Texas.

While demand for petroleum in the United States increased 3.9 per cent over 1947, national production of crude oil increased 8.3 per cent or 424,000 barrels per day. In addition this country produced 396,000 barrels per day of natural gasoline, which was 32,000 barrels daily above 1947 levels. Besides this domestically produced supply of 5,905,000 barrels per day, the United States imported 505,000 barrels of foreign oil daily compared with 437,000 barrels during 1947.

The closely allied natural gas industry also continued its spectacular growth, breaking all previous records during 1948. Marketed production rose to an annual total of 4.9 trillion cu ft up 0.5 trillion from the preceding year. At this level, sales of natural gas were twice those of 1939 and one fourth greater than in 1945.

To provide enlarged facilities for handling record volumes, the oil and gas industries conducted a vigorous development and construction program. The greatest drilling campaign in history took place, with a total of 39,319 wells completed during 1948, to far surpass the previous peak of 35,213 completions made in 1947. The construction of pipe lines reached unusual heights. A total of almost 15,000 miles of new pipe lines were placed in operation during the year, nearly twice the previous peak. Approximately half of the new pipe lines were natural gas systems. Placing new processing units on steam boosted the nation's refining capacity to 6,076,000 barrels daily by the end of 1948, an increase of 405,000 barrels per day over a year ago.

Noteworthy in 1948 is the estimated LP-gas marketed, totaling 2,600,000,000 gallons, an increase of 29.5 per cent over 1947. It is significant that of the total nearly fifty per cent goes into domestic consumption.

The most important of the many factors that make up these prodigious accomplishments are the price of products and the improvement in the availability of materials. While earnings reached record levels, decreased purchasing power of the dollar, in many cases, did not entirely provide the necessary funds for the huge capital investments of the past two years.

Acceleration of tidelands development, especially along the Gulf Coast, continued at a high rate during 1948. As of Jan. 1, 1949, $27,000,000 has been expended on exploration work. It is estimated that 45 drilling prospects have been leased off Louisiana and fifteen off Texas coasts. Fifteen prospects of the 45 have each had at least one well drilled, resulting in discoveries of four oil (26.64%); five gas (33.3%); and six dry (39.96%). Two prospects of the fifteen off Texas, with one well drilled, have resulted in one dry and one gas well. Active operations are in 28 off Louisiana and four off Texas.

While domestic activity has continued at a high rate in the older recognized producing areas, with attendent successes, we note an increasing interest in the Rocky Mountain area. Outside the United States the Persian Gulf area and Canada have had the spotlight.

Technologically, advancements have continued in all departments at an accelerated rate—witness the growth of petroleum research laboratories and demand for research and applied engineering personnel.

In summary the petroleum industry's achievements reflect tangible evidence of the worthiness of free enterprise as we know it.

# PRODUCTION . . . *soars above last year; output falls off proportionately in world*

By **E. G. DAHLGREN** • CHAIRMAN, PRODUCTION REVIEW COMMITTEE, AIME

Raw material producers of the industry did it again. Despite difficulties of obtaining steel, other materials, and foreign exchange, they obtained from the earth's subsurface throughout the world a record total of 3.4 billion barrels of crude oil. On a daily-average basis, this amounted to 9.3 million barrels and compares with 8.3 million in 1947. The increase of a million barrels daily was a little over 12 per cent more than was produced in the previous year. During the last quarter of 1948, it is estimated that world output of crude reached approximately 9.7 million barrels daily or at the annual rate of 3.5 billion barrels.

The producing operators of the United States accomplished what was thought by some to be an almost impossible feat a few years ago by producing at the average rate of 5.5 million barrels daily for the year. Peak operation in the United States in 1948

**Table 1**

**World Production of Crude Oil**

| | In Thousands of Barrels of 42 Gallon Per Day | | | |
|---|---|---|---|---|
| | 1947 | Estimated 1948 | Change 1948 vs 1947 | 1948 Per Cent of Total World |
| United States | 5,085 | 5,512 | + 427 | 59.2 |
| Venezuela | 1,191 | 1,339 | + 148 | 14.4 |
| Mexico | 154 | 160 | + 6 | 1.7 |
| Other Western Hemisphere | 247 | 263 | + 16 | 2.8 |
| Total Western Hemisphere | 6,677 | 7,274 | + 597 | 78.1 |
| Europe (except Russia) | 128 | 132 | + 4 | 1.4 |
| Near and Middle East | 838 | 1,127 | + 289 | 12.1 |
| Other Eastern Hemisphere | 95 | 185 | + 90 | 2.0 |
| Total Eastern Hemisphere (except Russia) | 1,061 | 1,444 | + 383 | 15.5 |
| Total World (except Russia) | 7,738 | 8,718 | + 980 | 93.6 |
| Russia | 543 | 600 | + 57 | 6.4 |
| TOTAL WORLD | 8,281 | 9,318 | +1,037 | 100.0 |

was 427,000 barrels daily higher than the previous peak year, an increase of 8.5 per cent. In the latter part of 1948, United States production exceeded 5.7 million barrels daily or over 600,000 barrels daily higher than the average for the full year 1947. This record achievement, however, did not keep the United States from losing position; in 1948 its share of world output dropped below 60 per cent for the first time since the early thirties.

Demand on the foreign operators throughout 1948 for ever increasing quantities of crude oil also forced foreign production to new peak levels. It averaged 3,206,000 barrels daily, excluding Russia, in 1948, or 553,000 barrels daily, 21 per cent more than in 1947. It was the first time in the history of the industry that foreign output, excluding Russia, climbed over the 3,000,000 barrels daily mark. This feat occurred in the United States in the year 1936. Including Russia, about which little is known, at 600,000 barrels daily, production outside the United States reached 3.8 million barrels a day or the level of crude output in the United States in the year 1941.

The gain in position in the foreign producing region was accomplished principally through increased output in the two great foreign producing basins—the Caribbean and the Middle East. The two minor producing areas of the Caribbean region showed slight decreases in output, the Colombian decline being caused principally by labor strife in 1948. Venezuelan oil was withdrawn at a new peak level of 1,339,000 barrels daily in 1948. This was 148,000 barrels daily more than 1947 or 12 per cent. Two producing regions accounted for most of the increased output. The older Bolivar coastal fields contributed an increase of 58,000 barrels daily and the new cretaceous area in the La Paz and Mara fields yielded about 60,000 barrels daily more in 1948 than 1947. Output from the cretaceous sands in these two fields jumped from an average of about 100,000 barrels daily in 1947 to 160,000 barrels daily in 1948. Major extensions were made in several of the producing areas in 1948.

### Table 2

### Comparison of U. S. Crude-Oil Production by Districts and the More Important States Within the Districts

| | Year 1946 | | Year 1947 | | Estimated Year 1948 | |
|---|---|---|---|---|---|---|
| | Thousand Barrels | Barrels Per Day | Thousand Barrels | Barrels Per Day | Thousand Barrels | Barrels Per Day |
| District 1 | 20,868 | 57,173 | 20.389 | 55,860 | 20,538 | 56,115 |
| Oklahoma | 134,794 | 369,299 | 141,019 | 386,353 | 153,961 | 420,658 |
| Kansas | 97,218 | 266,351 | 105,346 | 288,619 | 110,102 | 300,825 |
| Indiana | 6,726 | 18,427 | 5,853 | 16,036 | 6,884 | 18,809 |
| Illinois | 75,297 | 206,293 | 66,459 | 182,079 | 64,739 | 176,883 |
| District 2 | 344,949 | 945,066 | 347,689 | 952,573 | 364,793 | 996,702 |
| Louisiana | 143,669 | 393,614 | 160,291 | 439,153 | 180,631 | 493,527 |
| Arkansas | 28,375 | 77,740 | 29,990 | 82,164 | 31,593 | 86,320 |
| Mississippi | 24,298 | 66,570 | 35,017 | 95,937 | 45,856 | 125,290 |
| New Mexico | 36,814 | 100,860 | 41,127 | 112,678 | 47,868 | 130,787 |
| Total Texas | 760,215 | 2,082,781 | 819,427 | 2,245,005 | 902,876 | 2,466,874 |
| Gulf Coast | 241,771 | 662,386 | 258,936 | 709,414 | 268,642 | 733,995 |
| West | 192,296 | 526,838 | 222,903 | 610,693 | 271,501 | 741,806 |
| East | 120,789 | 330,929 | 117,523 | 321,981 | 112,714 | 307,962 |
| District 3 | 993,751 | 2,722,605 | 1,086,248 | 2,976,021 | 1,209,514 | 3,304,683 |
| Wyoming | 38,977 | 106,786 | 44,238 | 121,200 | 54,393 | 148,615 |
| District 4 | 59,658 | 163,446 | 68,679 | 188,162 | 81,606 | 222,967 |
| District 5 (California) | 314,713 | 862,227 | 333,102 | 912,608 | 340,901 | 931,423 |
| Total—United States | 1,733,939 | 4,750,517 | 1,856,107 | 5,085,224 | 2,017,352 | 5,511,890 |

Source: Bureau of Mines, 1946, 1947, and ten months 1948; API two months 1948 estimation basis.

### Table 3

### Well Completions and Wells Drilling

| | Total Wells Completed | | Total Wells Drilling on December 1 | |
|---|---|---|---|---|
| | 1947 | 1948 | 1947 | 1948 |
| Arkansas | 336 | 309 | 38 | 39 |
| California | 2,070 | 2,886 | 340 | 374 |
| Illinois | 2,133 | 2,511 | 221 | 301 |
| Indiana | 662 | 1,122 | 84 | 127 |
| Kansas | 2,761 | 3,230 | 394 | 412 |
| Kentucky | 765 | 810 | 91 | 42 |
| Louisiana | 1,672 | 2,322 | 231 | 288 |
| Michigan | 919 | 893 | 128 | 143 |
| New Mexico | 559 | 607 | 140 | 134 |
| New York, Pennsylvania, West Virginia | 5,834 | 4,840 | 689 | 597 |
| Oklahoma | 4,058 | 4,271 | 548 | 668 |
| Rocky Mountains | 799 | 1,212 | 303 | 367 |
| Texas | 9,293 | 12,223 | 981 | 1,378 |
| Others | 1,946 | 1,909 | 328 | 274 |
| Total United States | 33,807 | 39,145 | 4,516 | 5,144 |

Source: Oil and Gas Journal.

The largest percentage gain in the Western Hemisphere was accomplished in Canada where output increased from 20,000 barrels daily to 32,000 barrels daily or 60 per cent. The extension of the Leduc field and

### Table 4

### Exploratory Completions 1947 vs. 11 Months 1948

| | 12 Months 1947 | | 11 Months 1948 | |
|---|---|---|---|---|
| | Total Exploratory Tests | Oil and Gas Discoveries | Total Exploratory Tests | Oil and Gas Discoveries |
| Alabama | 24 | 0 | 19 | 0 |
| Arizona | ..... | ..... | 1 | 0 |
| Arkansas | 86 | 12 | 106 | 8 |
| California | 301 | 32 | 238 | 50 |
| Colorado | 51 | 7 | 52 | 6 |
| Florida | 27 | ..... | 23 | 1 |
| Georgia | 5 | ..... | 3 | 0 |
| Illinois | 584 | 144 | 583 | 88 |
| Indiana | 156 | 25 | 281 | 40 |
| Kansas | 417 | 73 | 507 | 75 |
| Kentucky | 71 | 8 | 57 | 8 |
| Louisiana | 363 | 88 | 338 | 113 |
| Maryland | ..... | ..... | 1 | 0 |
| Michigan | 259 | 21 | 243 | 20 |
| Mississippi | 100 | 12 | 112 | 7 |
| Missouri | 18 | 0 | 21 | 0 |
| Montana | 27 | 6 | 38 | 5 |
| Nebraska | 2 | 0 | ..... | 0 |
| New Mexico | 79 | 13 | 92 | 18 |
| New York | ..... | ..... | ..... | ..... |
| North Carolina | 1 | 0 | ..... | 0 |
| Ohio | 55 | 12 | 48 | 12 |
| Oklahoma | 638 | 107 | 514 | 104 |
| Oregon | 1 | 0 | ..... | 0 |
| Pennsylvania | 7 | 0 | 4 | 0 |
| South Dakota | ..... | ..... | 1 | 0 |
| Tennessee | 18 | 0 | 37 | 2 |
| Texas | 2,153 | 538 | 2,725 | 615 |
| Utah | 4 | 0 | 18 | 5 |
| Virginia | ..... | ..... | 1 | 1 |
| Washington | 2 | 0 | 2 | 0 |
| West Virginia | 11 | 3 | 8 | 4 |
| Wyoming | 79 | 29 | 112 | 37 |
| Total—United States | 5,539 | 1,130 | 6,185 | 1,219 |
| Oil Wells | ..... | 869 | ..... | 958 |
| Distillate Wells | ..... | 115 | ..... | 113 |
| Gas Wells | ..... | 146 | ..... | 148 |
| Total Successful | ..... | 1,130 | ..... | 1,219 |

Source: World Oil (Oil Weekly).

the discovery of Woodbend and Redwater were major accomplishments last year. Toward the latter part of the year, Canadian production was approaching 40,000 barrels daily.

In the Eastern Hemisphere, the Middle East sector yielded an average of over a million barrels daily for the first time in its short producing history. The countries bordering on the Persion Gulf produced 1,056,000 barrels daily in 1948 as compared with 739,000 barrels daily in 1947, an increase of 317,000 barrels daily or 43 per cent. This was the largest volumetric gain outside of the United States. Including Iraq, where production was down about 28,000 barrels daily or 28 per cent as a result of political strife, this entire Middle East region contributed 12 per cent of the world's output and a little over one third of the total foreign output, excluding Russia. In 1948, important discoveries and extensions occurred as a result of exploratory drilling in the Middle East.

As is always the case, little information is available about the yield of crude from the fields in Soviet Russia. It is estimated, however, that output did not exceed 600,000 barrels daily. It is an interesting commentary that output in Soviet Russia and Sakhalin has just about reached prewar levels this year. It is also of interest that output in the three great producing regions where free enterprise goes unhampered, the United States, the Caribbean, and Middle East, amounted to 8.1 million barrels daily last year or nearly twice the prewar output of 4.3 million barrels daily.

The fields in the Far East, where rehabilitation continued in spite of political difficulties, produced 151,000 barrels daily last year. This was 81,000 barrels daily or 117 per cent more than was produced in 1947.

American-owned crude-oil production in foreign countries, except Russia, totaled some 1.6 million barrels daily in 1948. This was about 400,000 barrels daily or 35 per cent higher than last year, and represented 50 per cent of the total. In 1947, the American-company crude position amounted to 46 per cent. Natural gasoline, synthetic production, etc., added about 450,000 barrels daily to the crude raw material supplies of the world.

In the United States, production in Texas increased over 83 million barrels or about 10 per cent (Table 2). Production in Louisiana increased over 20 million barrels or about 13 per cent. Mississippi's gain of over 10 million barrels or about 31 per cent established another all-time record for the State. Oklahoma increased its production over 12 million barrels or about 9 per cent. Kansas production averaged over 300,000 barrels per day to surpass 1947 daily production by 12,000 barrels. New Mexico increased its production by 6½ million barrels over 1947. Wyoming stepped up its 1948 production over 1947 by more than 10 million barrels. California increased its production by nearly 8 million barrels. Illinois production declined by 1.8 million barrels.

Total well completions in the United States were about 16 per cent greater in 1948 than in 1947. Important increases in drilling activity took place in Illinois, Indiana, Louisiana, California, Kansas, Texas, and the Rocky Mountain area. As shown in Table 3, drilling declined in Arkansas, Michigan, and the area including New York, Pennsylvania, and West Virginia.

Exploratory drilling, operations in wildcat and field extension areas, or testing new prospective producing zones in fields (Table 4) resulted, in the first eleven months, in 1219 successful wells out of 6185 completions, or a success ratio of 20 per cent, the same as in 1947.

The principal source of new oil in 1948 came from discoveries in Texas, South Louisiana, Oklahoma, and the Rocky Mountain region. The reserves of West Texas have been boosted sharply. The Ellenburger lime in the Permian Basin and in North Texas is creating much interest. The shortage of pipe stimulated exploration in the shallow areas in South Texas.

Offshore drilling in the Gulf of Mexico, off Texas and Louisiana, was on a major scale during the year. The East Texas field had 50 new wells completed in December to make the field total 22,424 producing wells. Texas recovered 84 million barrels of petroleum liquids from natural gas. West Texas activity rose to record levels during 1948 with the development of Pennsylvania production on the east side of the Permian Basin. Another factor was the accelerated drilling program on the Central Basin platform and in the Midland Basin.

North Texas was active with new discoveries in Young, Archer, Throckmorton, Grayson, and Denton Counties. The Chico field in Wise County was active.

The Crossroads pool of northeastern Lea County in New Mexico, may prove to be the State's outstanding discovery of the year. Other pools were found in the McKee section of the Simpson and in the Devonian.

## Table 5

## Crude Oil Production in Foreign Countries

| | In Barrels of 42 Gallons Per Day | | |
|---|---|---|---|
| | 1947 | 1948 | Per Cent Change |
| Caribbean Area: | | | |
| Venezuela | 1,190,800 | 1,338,600 | + 12.4 |
| Colombia | 68,100 | 65,100 | − 4.4 |
| Trinidad | 55,700 | 55,000 | − 1.3 |
| Total | 1,314,600 | 1,458,700 | + 11.0 |
| Mexico | 153,800 | 160,000 | + 4.0 |
| Argentina | 59,900 | 63,300 | + 5.7 |
| Peru | 35,000 | 38,500 | + 10.0 |
| Balance Latin America | 8,900 | 8,900 | ....... |
| Canada | 20,000 | 32,000 | + 60.0 |
| Total Western Hemisphere (except United States) | 1,592,200 | 1,761,400 | + 10.6 |
| Rumania | 78,000 | 78,000 | ....... |
| Hungary | 11,900 | 10,000 | − 16.0 |
| Balance Europe | 38,500 | 43,700 | + 13.5 |
| Total Europe (except Russia) | 128,400 | 131,700 | + 2.6 |
| Egypt | 25,500 | 35,000 | + 37.3 |
| Near and Middle East: | | | |
| Iraq | 99,200 | 70,900 | − 28.5 |
| Persian Gulf | 738,600 | 1,055,900 | + 43.0 |
| Total | 837,800 | 1,126,800 | + 34.5 |
| Far East | 69,400 | 150,700 | +117.1 |
| Total Foreign (except Russia) | 2,653,300 | 3,205,600 | + 20.8 |
| Russia | 543,000 | 600,000 | + 10.5 |
| Total Foreign | 3,196,300 | 3,805,600 | + 19.1 |

The high point in Oklahoma in 1948 was the development of the "Golden Trend" region with Garvin County as the focal point with parts of McClain, Grady, Stephens, and Carter Counties. An important test was the Gulf-Mainka well in Grady County which found production in the Ordovician at a total depth of 13,250 ft. The greater Seminole area was active. The Elk City field, discovered in December, 1947, gives promise of becoming a large producing area. The Denver well in Caddo County was the deepest test with a total depth of 17,094 ft.

Kansas enjoyed one of its biggest years with drilling volume exceeded only by the boom years around 1918 following the opening of the El Dorado and Augusta fields. Natural-gas production was approximately 202 billion cu. ft. Rooks County was the leader with 11 new oil pools, followed by Barton County with 10, and Stafford County with seven oil pools and one gas pool. The two outstanding new Kansas pools were the DeGeer pool in Barber County and Northampton pool in Rooks County. The year saw Nemaha and Seward Counties get their first commercial oil production.

Well completions in North Louisiana were higher than a year ago owing to redrilling activities in the shallow Caddo-Pine Island and Bellevue fields. The new Saline Lake field in Catahoula Parish shows indications of being a major discovery.

Rocky Mountain region production in 1948 broke all previous records. The Rangely field in Colorado ranks as the largest field with a present daily production of 55,000 barrels. Utah discovered its first commercial oil production. Wyoming has the deepest flowing well at West Poison Spider at a total depth of 14,309 ft.

Illinois drilling activity increased 18 per cent over 1947 with the largest amount of drilling since 1941. Wayne County led in oil drilling and in successful completions, followed by Wabash, Clay, and Gallatin Counties. These four counties had about 47 per cent of all drilling and 45 per cent of successful completions.

In California, the most important discoveries were made in the Kettle-man Middle Dome, Cuyama Valley, the Barnsdall discovery east of Coalinga, Newhall, and the Hancock Oil Co. discovery northeast of the Ten Section field in Kern County. The Russell Ranch field in Cuyama Valley had 35 wells producing 6000 barrels per day at the end of the year.

It is estimated that secondary-recovery methods are being applied to approximately one half million acres in the United States. The average daily production from these projects is estimated at 250,000 barrels. In addition, considerable interest is being shown in these methods in foreign countries.

Exploratory activity was at a high point during the year with the peak of 623 geophysical crews in operation as of June 30. Rotary drilling activity was also at an all-time high with a total of 2422 rigs operating as of October 31. Natural gasoline operations reached an all time peak during the year. Natural-gas sales in 1948 were up 11.4 per cent over 1947. The production of liquid petroleum gas increased 48 per cent in 1948 over 1947.

The assistance of C. J. Bauer, of the Standard Oil Co. (New Jersey), in the preparation of this review is gratefully acknowledged. Mr. Bauer furnished the data and information on world operations.

# PRODUCTION TECHNOLOGY . . . *advances paced by mechanized drill rigs, Hydrafac process, off shore drilling on the Gulf*

By **R. W. FRENCH** • CHAIRMAN, COMMITTEE ON PRODUCTION TECHNOLOGY, AIME

With increasing personnel and time applied to problems of petroleum production technology following wartime diversion, the industry witnessed a heartening gain in both theoretical and practical development. Of course, many advances relate to problems of long standing and, generally, constitute progress reports of varying magnitude, but some significant items such as the Hydrafac process for increasing well productivity and the field use of acoustic-impedance lodging were new.

The ever present effects of economic forces in the industry, such as the basic supply-demand ratio and its effect upon oil and gas prices, stimulated drilling and development to unprecedented levels. The same forces pushed water-flooding and gas-injection activity to comparatively higher intensity. Design, manufacture and service testing of new equipment and instruments regained much of the ground lost during war years. Laboratory work paralleled the foregoing rate of activity demonstrating that the industry is spending substantial sums and making considerable progress in reducing the number of unknown factors and relationships affecting the following:

(1) Flow of multiphase fluids through reservoir rocks.

(2) More accurate estimates of initial and subsequent volume of fluids in reservoir rocks in terms of recoverable volumes.

(3) Improved understanding and control of fluid displacement through reservoir rocks naturally or through the use of extraneous fluids.

(4) Understanding of mineralogical composition and distribution of reservoir rocks as affected by intrusion of various fluids, and of the discrepancies between properties measured in a laboratory and those of the same material in situ.

(5) Ultimate recovery from reservoirs—particularly solution-gas driven pools—as a result of relative approach to equilibrium conditions as previously assumed.

(6) Actual deliverability and improved estimates of ultimate recovery from gas reservoirs despite the masking effect of pressure-withdrawal transients.

(7) Volumetric-phase changes with pressure in liquified-gas reservoirs which have been confused frequently with retrograde-gas pools and in which recognition of shrinkage and control thereof has an important effect on final profits.

The most important new frontier of activity was, by all odds, the invasion of the Continental Shelf. Some fifty wells have now been drilled or are projected and the industry has opened a field for technological progress comparable in some respects to that facing the drilling and producing industry twenty years ago. In addition to the apparent problems of different natural environment and accompanying forces from wind and water, new techniques may be envisioned in the fields of weather and state-of-sea forecasting, use of frequency modulated radio, and radar—all of which will bring into our group new technologists such as naval architects, marine engineers, meteorologists, oceanographers, marine biologists, and others. Production developed to date faces extreme costs which the industry confidently expect to be reduced to some now unpredictable extent through the continued application of sound engineering methods.

Among the outstanding specific developments is the Hydrafac process for increasing the productivity index or rate of production of oil and gas wells. This technique combines chemistry with mechanics to force a viscous, jellied gasoline into the producing formation by means of high pressure through the use of packers. If the imposed pressure is sufficient to open fractures in the producing formation, the fluid moves in, carrying a bridging agent such as graded-sand particles. Following release of pressure and chemical reversion of the jell

**Size and weight** of drilling equipment are approaching the limit of human strength.

to a low viscosity liquid, the injected material returns to the well bore leaving the bridging agent behind to retain the open channels. Early field tests in Hugoton, Frannie, Rangely, and various areas of Oklahoma and Texas have demonstrated surprising numbers of successful applications—those in which higher rates of production were achieved and maintained at least long enough to return the cost of the job and in some cases with relative permanence.

A large drilling rig demonstrated the mechanical feasibility of a relatively high degree of mechanization. Slips, tongs, and also floor and derrick-racking machinery do not require human contact—except for the indirect control. Relative time and cost savings are not known but with drilling-equipment size and weight approaching limits of human strength and endurance, this work holds promise of improved drilling and lower costs.

It is interesting to note that a cooperative nonprofit organization, open to anyone who cares to share the cost, was formed in 1948 to investigate and pursue the possibilities of low-drilling costs through applied research. This organization, with an initial three-year budget of nearly $800,000 and a present membership of more than 35 concerns and individuals, will lose no time in attacking the drilling problem upon which the industry spent some 1½ billion dollars in 1948.

Typical of recent logging methods, acoustic-impedance logging, utilizing a vibrating bar or tube to traverse the productive section, discloses differences in energy returned from the surrounding formation through electrical means. Unless the mud contains gas bubbles, the response is independent of mud properties; only mechanical limits of hoist limit the speed of logging; and the logs are not dependent on any transient conditions in the hole as they measure variations in hardness and density only.

The use of subsurface pressure, temperature, velocity, and water-locating instruments in wells, by running them down the annulus for increased effectiveness and lower cost, has resulted in development of special well heads with provision for special wire-line lubricators. In smaller casing, this requires offset tubing heads but, despite surprising success in handling instruments by wire lines in the annulus, there is still the need to eliminate those cases where the wire does wrap around the tubing, necessitating a recovery job. Several manufacturers are now designing offset tubing heads which will permit relative rotation to free the wire line without disconnecting the well head.

Following past advances protecting well productivity from reduction during drilling and remedial operations through intrusion of circulating fluid and suspended materials, relatively wide use of synthetics occurred in 1949. As a result of deeper drilling and better engineering supervision, this problem is now recognized in many areas formerly thought to be unaffected and the real value of higher productivity indices is increasingly understood as evidenced by the enlarged use of synthetic fluid materials and chemicals designed to improve the productivity of older wells through removal of drilling mud, silt, salt, and waxey residues or sludges. Surface-active material is demonstrating value in many cases, particularly in California.

# GAS TECHNOLOGY COMMITTEE . . . *reports reorganization, system of nomenclature, classification of gas reserves*

By **CARLTON BEAL** • CHAIRMAN, GAS TECHNOLOGY COMMITTEE, AIME

The Gas Technology Committee was composed of nine members representing the principal gas producing areas of the United States. The following has been accomplished:

(1) The committee has been reorganized from the "Gas Reserves Committee" to the "Gas Technology Committee," so as to cover the principal phases of the gas industry. The Gas Reserves Committee of 1948 has become the Reservoir Efficiency Subcommittee. Problems of production, transmission, measurement, and storage will be studied by a companion subcommittee.

(2) The duties and scope of the Reservoir Efficiency Committee have been outlined.

(3) Types of gas reserves have been defined.

(4) A system of nomenclature has been adopted.

(5) Two types of pool performance curves have been prepared.

(6) Two technical papers were prepared.

## reservoir efficiency problems

The subcommittee will evaluate methods of predicting gas reserves and compare volumetric methods of predicting reserves with actual field experience. Gas pools used for this type of research must necessarily be limited to those that are nearly depleted; however, it is hoped that there are sufficient pools in each of the various classes to make an informative analysis. This investigation may not be confined to near-depleted pools, provided there is a well established pressure-production decline for pools in the immediate stage of depletion.

Methods of predicting gas reserves, as employed by most engineers, are accepted as going values of reservoir-gas-recovery efficiency and it would appear necessary at this stage to check actual experience encountered in nearby depleted pools. The fact that there is an important effect of abandonment pressures on the recovery efficiency of depletion-type gas reservoirs is accepted. It appears that much can be done to investigate this phase of the problem.

## classification of gas reserves

(A) Associated gas (free gas cap above black oil in same reservoir).

1. Depletion
2. Water drive

(B) Nonassociated gas

1. Condensate (past or current gas injection)
   a. Depletion
   b. Water drive
2. Pools without gas injection (dry gas)
   a. Depletion
   b. Water drive

(C) Dissolved gas (originally dissolved in crude oil)

1. Depletion
2. Water drive

The committee will compare actual field experience from at least one pool in each of the above reservoir classes. There is not a clear definition showing the difference between B-1 and B-2 pools, however, it may be generally stated that a condensate pool is not a dry-gas pool when it is commercially feasible to recover liquid production by gas injection. Nor is there a clear definition showing the difference between B-1 pools and C pools. The Committee can do much to clarify this point as to when an oil field becomes a condensate pool; but in any event it would appear that a definition should be drawn in simple terms, such as oil gravity and gas to oil ratio without relying on laboratory analysis of a liquid sample.

## nomenclature

The committee has prepared a system of nomenclature, which may prove helpful in standardizing calculations.

A—Drainage area for the well—Acres
C—An observed coefficient for a gas well—Cu ft/D/$\text{psi}^2$
G—Specific gravity of gas—Air—1.00
h—Average gas sand thickness—Feet
L—Depth to midpoint of sand—Feet
n—Cotangent of slope from horizontal of q and square of pressure relationship—No units
O—Porosity of sand to air—A decimal fraction of Reservoir Volume
P—Pressure—psi
Psia—Pounds per square inch absolute
Psig—Pounds per square inch gauge using 14.7 psi for one standard atmosphere
q—Rate of gas flow at standard conditions—mcf/D
Qr—Ultimate gas recovery—mcf
r—Commercially recoverable gas reserves—mcf
R—10.75
Sg—Space available for gas (1-Sw)—Decimal fraction of void space
Sw—Original interstitial water saturation—Decimal fraction of void space
t—Reservoir temperature—°F

T—Reservoir temperature (t 460)—°F Rankin
X—Producing drawdown; a fraction of the static reservoir pressure—A fraction
Z—Compressibility factor—$\frac{PV}{NRT}$ when N—pound moles present

SUBSCRIPTS

e—Final conditions upon abandonment in reservoir.
f—Flowing conditions in well bore.
o—Original conditions in reservoir.
s—Static conditions in well bore.
w—At well casing head.
1,2,3,4—At temperature and pressure indicated.

# ECONOMIC REVIEW . . . *discloses peak prices for oil, oil products, with all demands being met*

By **ROBERT J. BRADLEY** • CHAIRMAN, ECONOMIC COMMITTEE, AIME

Economic reviews are often dull reading because they usually contain a mass of dry statistics. Final figures for 1948 as to the total amount of production, refining, shipments, and sales are already, or shortly will be, abundantly available in many trade journals and association or government bulletins. It seems appropriate, therefore, in reviewing 1948 from the standpoint of petroleum economics, to avoid a recapitulation of figures and, instead, to lay stress upon significant developments of the year.

The year probably saw the peak in crude-oil prices for the present major business cycle. There now seems to be sufficient agreement between economists to postulate that the peak of business in general has been reached. While there are, of course, exceptions to this in particular industries, and while it seems not unlikely that the present level of crude prices will hold for some months to come, it also seems probable that we are likely to see somewhat lower prices over a considerable period before we again reach or exceed the peak prices of 1948. In order to be realistic, we should consider the peak in crude prices as having been reached when premiums were widespread throughout the Mid-Continent area and when around ten per cent of the purchases were at a posted price of $3 per barrel.

In addition to a stabilization of crude prices in 1948, a similar break began to be evidenced in the spot prices of bunker and fuel oil, followed by some downward adjustments in other product prices toward the end of the year. While some concern has been shown about this "break" in prices, it is undoubtedly a healthy and normal adjustment and should tend to produce a stabilized product-price situation which is far more desirable than a violently fluctuating market.

More significant than the attainment of peak prices, but of less individual interest, is the fact that during 1948, operating without price controls and with the natural encouragement of high prices, the industry successfully attained a level of production of both crude and products, which has met all demands. The real importance of this creation of a normal balance of supply and demand is that it has removed the threat of additional Federal Government control and interference. Barring possibilities of a national emergency, or a further shift to the left in the nation's politics, it seems reasonable to look upon 1948 as the year in which the industry defeated those in high political positions who insisted that the public weal, as far as petroleum was concerned, could best be served by a controlled economy.

In 1948, the nation also became, for the first time in the adult memory of many of the industry's leaders, a net importer of crude oil in sufficient quantities to require recognition of imports as a major factor in our supply and demand picture. Without comment upon the arguments for or against this phenomenon, it must be recognized that imports are playing an important role in balancing supply against demand. While the question will long remain moot as to whether or not the domestic industry alone can continually meet demand successfully, there is little doubt that the demand during 1948 could not have been met without substantial imports.

Along with the increasing importance of imports, the year was marked by a recognition on the part of many smaller companies that somewhere down the road they may become increasingly dependent upon foreign supplies. We have witnessed the unique circumstances of several domestic competitors combining in order to enter the expensive, and not always lucrative, foreign field. As a consequence, major representation in foreign developments by a larger segment of the industry is being accomplished. The large amounts of capital that are required to carry on adequate exploratory programs abroad have made it necessary for some rather strange bedfellows to pool their resources. The fact that they have been able to do this in other countries without fear of restriction by our domestic antitrust laws, should ultimately save some of these companies from being virtually forced out of the producing end of the business when their reserves in this country have been exhausted.

From the standpoint of finance, the year of 1948 saw the largest peacetime capital expenditures in the industry's history. These expenditures included not only refinery and producing property expansion, but an unusual amount of construction of pipe lines and tank ships. The major part of these expenditures were met out of earnings, and consequently most companies have paid out a smaller percentage of earnings in dividends than in the past. While shortsighted stock holders may deplore this fact, the farsighted stock holder should be grateful to management which has realistically recognized the necessity for plant expansion and, more importantly, has recognized that the tremendous earnings of the year were made from the production of oil which was found in past years at a relatively low cost. The cost of finding oil today is probably more than four times greater than it was ten years ago. The year has also been marked by the inability of the industry to obtain equity money easily by the sale of additional stock to cover such expansion and the consequent necessity of a major shift to the use of funded debt.

Robert J. Bradley

Finally, in 1948, we saw the use of the powers of state regulatory bodies toward the end of the year in reducing production to stabilize supply and demand. This marks the reversal of the trend of the past several year during which time allowables were continuously revised upward to a point where the maximum efficient rates of production, in some instances, were being exceeded. This stabilization of supply and demand is effectively supporting the present price structure. Even though revisions upward and downward are generally justified by engineering studies, these recent downward turns in production allowables were largely brought about by economic factors.

# RESEARCH COMMITTEE . . . *stimulates interest in basic problems.*

By **J. E. SHERBORNE** • CHAIRMAN, ENGINEERING RESEARCH COMMITTEE, AIME

The importance of the university and related research institutions as a source of man power for the constantly expanding amount of industrial research undertaken by business firms today cannot be overemphasized. The only satisfactory way in which to train an individual for research is to give him research to perform. That our universities and academic institutions have been eminently successful in developing high-quality research investigators is readily apparent. Considering that under present conditions a large number of the individuals trained in research find their way into industrial laboratories, the closest possible liaison between industrial personnel and those engaged in academic pursuits appears required.

With the above in mind, the Engineering Research Committee of the Petroleum Branch has undertaken to bring before the several universities and research institutions throughout the country subject matter, as yet unsolved or, at best, partially solved problems confronting the petroleum technologist. The committee has recognized that other organizations have been concerned with broad fundamental research studies sponsored by industry and conducted by university personnel. It has carefully avoided duplicating such effort, and as a consequence has had, as a program, the following three objectives: (1) to ascertain from industrial personnel, problems confronting the industry which require additional research; (2) to choose from among these, the subjects believed to be most suitable for graduate study; and (3) to call attention to the various universities, colleges, research institutions, and to the industry the need for the solution of these problems.

In order to accomplish these objectives, the committee canvassed the opinion of a number of those in industry engaged in research or otherwise associated with petroleum technology. The response to the committee survey was most gratifying and, as a result, a large number of subjects were listed and classified. Particular emphasis was placed on compiling subjects which could be suitably undertaken by graduate students working for advanced degrees, anticipating that the resulting research would provide satisfactory thesis material.

The report of the committee was received by those in academic institutions with considerable enthusiasm. Numerous letters were received indicating that a number of the subjects suggested would be undertaken. Others indicated that research was already underway at other institutions on one or more of the subjects or upon certain phases of some of the listed material. Still others expressed interest in obtaining further details relative to certain of the suggested research topics.

# ALL INSTITUTE SECTION

APPEARING IN:
- MINING ENGINEERING
- JOURNAL OF METALS
- JOURNAL OF PETROLEUM TECHNOLOGY

## *AIME Suffers Its Worst Financial Year With Operating Deficit of $82,000*

As had been expected, the AIME had the largest deficit in its history in 1948, as shown by the report of the Treasurer presented before the Board of Directors at their meeting at Institute headquarters on Jan. 19. Expenditures for the year totaled $428,000 (of which $237,000 was for publications, a record figure), compared with income of $346,000 including some $11,000 received from voluntary contributions. This left a net operating deficit of about $82,000, which was partly met by an appropriation of $10,000 from the Rocky Mountain Fund to cover the cost of printing the Transactions volume on Mining Geology; and $47,000, which was borrowed from the Special Fund for Publications, as provided in the budget. The remaining $24,000 was met by transferring $32,500 from the General Reserve Fund, representing the entire amount accumulated from the payment of initiation fees prior to 1926, since which time they have been used for operating income.

Income from advertising and sales of "Mining and Metallurgy" was some $14,000 less than the budgeted figure, and the cost of all publications exceeded the budget by about $33,000, chiefly for two reasons: (1) provision for inclusion in Transactions volumes of all material published in the Technologys up to the end of 1948; and (2) additional expense incurred in printing "Mining and Metallurgy" during the seven months' strike at the regular printers, plus higher costs after the strike was settled. Institutional expense was as anticipated except for some $4000 increase in expense charged to Divisions for added help and traveling, and some $3000 in additional meeting expenses. Some $6,500 was saved from the budget figure for General Office expenses. The book value of investments increased about $38,000, and the market value of securities held by the Institute at the end of the year was 103.6 per cent of cost.

J. L. Gillson, chairman of the Special Committee on Democratization, made a progress report, summarizing his final report to be made at the Annual Meeting. The principal things suggested were: (1) Reorganization of the Section Delegates' Conference and replanning of their meetings. (2) Greater field activity by the Secretary, with the appointment of an office manager to supervise the headquarters staff. (3) A field secretary for the Mining Branch, preferably making his headquarters in Salt Lake City. (4) Greater assumption of responsibility by Directors for reporting to the Board the sentiment of members in their geographical districts. (5) Inclusion of a few capable younger men in the Directorate. (6) Appointment of a committee or an individual to listen to and reply to grievances, seeking out their cause, and either rectifying them or bringing them to the attention of the Secretary.

Officers of the newly organized Mineral Economics Division of the Institute were appointed by President Wrather as follows: Chairman, Elmer W. Pehrson; Vice-Chairmen, C. H. Behre, Jr., W. H. Voskuil, and Felix E. Wormser; Secretary-Treasurer, Richard J. Lund; Executive Committee, for one year, Joseph A. Corgan, John D. Gill, and George A. Lamb.

On the recommendation of the Committee on Honorary Memberships, Harvey S. Mudd, chairman, the Board voted to confer Honorary Membership on Erle V. Daveler, Vice-President since 1940 and currently chairman of the Finance Committee. The citation reads, "Erle Victor Daveler—Engineer of rare attainments; Exemplar of the best in professional ideals; Director and Officer of the Institute for a continuous period of twenty years and unfailingly a diligent, able, and devoted guardian of its material well-being and supporter of its traditional purposes and tenets."

Revised bylaws for the Ohio Valley Section were approved, giving increased recognition to students and Junior Members in the Section's activities. A new Student Chapter of the

AIME was recognized at Rutgers University, with Helgi Johnson as Faculty Sponsor and J. D. Grothe, Counselor. Henry Krumb was reappointed chairman of the Rocky Mountain Income Committee for a three-year term, and Scott Turner and Herbert G. Moulton, as past Presidents, with James L. Head as alternate, were named to serve, with the current President and Secretary, on Engineers Joint Council. Wilfred Sykes was named to represent the Institute at the presentation of the Washington Award to John Lucian Savage, on April 20, in Chicago. H. A. Maloney was appointed as a trustee of the AIME Pension Fund, succeeding A. B. Parsons.

Under the new Bylaws adopted last November, Junior Members transferring to the grade of Member or Associate Member must pay an initiation fee of $20. However, the Board felt that this was an injustice to those soon to qualify to change their status under the old bylaw without payment of an initiation fee, following completion of ten years as a Student Associate or Junior Member, or both. It was voted that Junior Members who had been on the rolls for ten years or more would be given until July 1, 1949, to change their status to the higher grade of membership without payment of any initiation fee. All Junior Members who qualify will be notified of this privilege.

President Wrather reported that he had been advised of a sentiment toward an increase in dues among members of the executive committees of the Pittsburgh Section and of the Coal Division.

After 2½ hours of discussion the meeting adjourned to the Engineers' Club where the usual dinner was served. André L. Brichant related a bit of his experience in the Department of Economic Affairs of the United Nations at Lake Success; Federico Luchsinger told of mining developments in Venezuela; and Ed B. Trueworthy, Jr., told of his recent experiences in spending Uncle Sam's money in Greece.

Directors present included: W. E. Wrather, President, who presided; H. J. Brown, Philip Kraft, W. W. Mein, A. J. Phillips, W. B. Plank, E. E. Schumacher, A. A. Smith, Jr., C. E. Weed, and Andrew Fletcher, Treasurer. George J. Donaldson was alternate for Newell G. Alford, and James L. Head for Russell B. Paul. Staff and guests included: E. A. Anderson, H. N. Appleton, J. V. Beall, André L. Brichant, J. L. Gillson, Edward Holloway, E. J. Kennedy, Jr., E. O. Kirkendall, Federico Luchsinger, H. A. Maloney, T. G. Moore, W. M. Peirce, E. H. Robie, Wheeler Spackman, George P. Swift, F. E. Van Voris, H. Y. Walker, L. E. Young, Walter Hover Hill, and Ed. B. Trueworthy, Jr.

## Calendar of Coming Meetings

MARCH

2 **Chicago Section, AIME. J. R. Van Pelt, Jr., on mineral economics.**
3 **Reno Branch, Nevada Section, AIME.**
3-5 Symposium on Southeast mineral resources, University of Tennessee, Knoxville.
4 **Columbia Section, AIME.**
6-9 AICE, regional meeting, Los Angeles.
7 **Boston Section, AIME.**
8 **East Texas Section, AIME.**
9 **El Paso Metals Section, AIME.**
9 **San Francisco Section, AIME.**
10-12 American Physical Society, Division of Solid State Physics, annual meeting, Hollenden Hotel, Cleveland.
14 **Mid-Continent Section, AIME.**
14-17 American Association of Petroleum Geologists, annual meeting, Hotel Jefferson, St. Louis.
15 **Gulf Coast Section, AIME.**
15 **Washington, D. C., Section, AIME.**
16 **Southwest Texas Section, AIME.**
17 **Carlsbad Potash Section, AIME.**
17 **North Pacific Section, AIME.**
17 **Utah Section, AIME.**
18 **Oregon Section, AIME.**
18 **Electric Furnace Steel Committee, Iron and Steel Division, AIME, Program Committee meeting.**
20-26 Second International Technical Congress, Cairo, Egypt.
21 **Detroit Section, AIME. R. K. Hopkins, on the Kellogg process.**
22 **Montana Section, AIME.**
Mar. 27-Apr. 11 ACS, 115th semi-annual meeting, San Francisco.
28 **Alaska Section, AIME.**
**Mar. 29-Apr. 1 Annual Safety Convention and Exposition, Hotel Statler (Pennsylvania), New York City.**
Mar. 31-Apr. 2 UNESCO, second national conference, Cleveland Auditorium, Cleveland.

APRIL

1 **Columbia Section, AIME.**
4 **Boston Section, AIME.**
5-6 Metal Powder Assn., 5th annual meeting and exhibit, Drake Hotel, Chicago.
6 **Chicago Section, AIME. Continuous casting at B&W Tube Co.**
6-10 AICE, regional meeting, Los Angeles.
7 **Reno Branch, Nevada Section, AIME.**
11 **Mid-Continent Section, AIME.**
11-14 National Assn. of Corrosion Engineers, 5th Annual Conference and Exhibition, Netherland-Plaza, Cincinnati.
11-15 Western Metal Congress & Exposition, Los Angeles, Calif.
12 **East Texas Section, AIME.**
13 **El Paso Metals Section, AIME.**
13 **San Francisco Section, AIME.**
13 **Southwestern New Mexico Section, AIME.**
15 **Oregon Section, AIME.**
18 **Detroit Section, AIME. W. L. Grube on the electron microscope.**
18-20 Midwest Power Conference, Sherman Hotel, Chicago.
18-20 **Open Hearth Conference, and Blast Furnace, Coke Oven and Raw Materials Conference, Palmer House, Chicago.**
19 **Gulf Coast Section, AIME.**
19 **Washington, D. C., Section, AIME.**
19-21 AIEE, Southwest district meeting, Baker Hotel, Dallas.
20 **Southwest Texas Section, AIME.**
20-23 ASCE, spring meeting, Oklahoma City.
21 **Carlsbad Potash Section, AIME.**
21 **North Pacific Section, AIME.**
21 **Utah Section, AIME.**
22-23 **New England Institute of Metals Division Regional Meeting, Hotel Sheraton, Springfield, Mass.**
22-23 Engineers' Day, Colorado School of Mines, Golden.
24-28 American Ceramic Society, national meeting, Netherland-Plaza, Cincinnati, Ohio.
25-27 Canadian Institute of Mining and Metallurgy, annual meeting, Windsor Hotel, Montreal.
25 **Alaska Section, AIME.**
26 **Montana Section, AIME.**

MAY

2-5 American Foundrymen's Society, 53rd annual meeting, St. Louis.
6-7 American Institute of Chemists, annual meeting, Chicago.
9-12 American Mining Congress, coal convention and exposition, Public Auditorium, Cleveland.
11-13 Engineering Institute of Canada annual meeting with International Management Congress hemisphere meeting, Chateau Frontenac, Quebec.
14 **Northwest Industrial Minerals Conference under auspices of Columbia Section, AIME, Spokane.**
25 **Iron and Steel Division, AIME, annual May dinner, Engineers Club, New York City.**

JUNE

16 Engineering Foundation, 29 W. 39 St., New York City.
June 27-July 1 ASTM, 52nd annual meeting, Chalfonte-Haddon Hall, Atlantic City, N. J.

JULY

9-23 Fourth Empire Mining and Metallurgical Congress, Great Britain.
15-24 Pan-American Engineering Congress, Rio de Janeiro.

SEPTEMBER

25-28 **Regional Meeting, AIME, Neil House, Columbus, Ohio.**
25-28 American Mining Congress, Western fall meeting, Spokane.
**Sept. 30-Oct. 1 Southern Ohio Section of Open Hearth Committee, AIME, fall meeting, Deshler-Wallick Hotel, Columbus.**

OCTOBER

5-7 **Petroleum Division, AIME, fall meeting, Plaza Hotel, San Antonio, Texas.**
17-19 **Institute of Metals Division, AIME, fall meeting, Allerton Hotel, Cleveland.**
28 **Pittsburgh Section of Open Hearth Committee and Pittsburgh Section, AIME, annual fall meeting, William Penn Hotel, Pittsburgh.**

DECEMBER

8-10 **Seventh Annual Conference, Electric Furnace Steel Committee, Iron and Steel Division, AIME, Hotel William Penn, Pittsburgh.**

FEBRUARY 1950

12-16 **Annual Meeting, AIME, Statler (Pennsylvania) Hotel, New York City.**

APRIL 1950

10-12 **Open Hearth Conference, and Blast Furnace, Coke Oven and Raw Materials Conference, Netherland-Plaza Hotel, Cincinnati.**

DECEMBER 1950

7-9 **Eighth Annual Conference, Electric Furnace Steel Committee, Iron and Steel Division, AIME, Hotel William Penn, Pittsburgh.**

# WILLIAM JESSE COULTER

## Director, AIME

William Jesse Coulter, son of Jesse and Mary Coulter, was born at Murray, Idaho, March 28, 1887. Bill, as he is known to his friends, graduated from High School in Spokane and entered Washington State College in 1907. His college course was interrupted for 2½ years spent in earning money and gaining practical mining experience in Nevada, Montana, and Sandon, B. C. He graduated in 1914 with a B.S. in mining.

After graduation he spent five years with the Granby Consolidated Mining, Smelting and Power Co., as engineer and foreman of two small mines on Prince of Wales Island in Alaska. He was then transferred to Anyox, B. C., where he served as miner, barman, shift boss, and assistant mine superintendent in the principal mines of the Company until 1926 when he moved to Terrerro, N. Mex.. as mine superintendent of the Pecos mine of The American Metal Co. In March, 1927, he joined the Climax Molybdenum Co. as general superintendent at Climax, Colo., and since that time has been continually on the Climax job as general superintendent and general manager.

During the years that Bill has guided the operations of the Climax company, the plant has been increased from 1000 to 20,000 tons daily. An underground operation of such size at an altitude of 11,300 ft involves many difficult problems which have been solved in a masterly fashion.

In 1929 his college conferred upon him the degree of Engineer of Mines, and again, in 1944, an honorary degree of Doctor of Laws. In 1935, the Montana School of Mines awarded him a professional degree of Mining Engineer.

In 1938, he established the Viola Vestal Coulter Foundation as a memorial to his first wife, Viola Vestal, who died in 1935. The purpose of this foundation is to help eight deserving students each year to obtain a college education.

After the death of his first wife he married Julia Vestal, a sister of his first wife, and they now live in Denver. Bill has three children—two married daughters and one son, a mining engineer who is following his father's footsteps by starting the hard way at the Bunker Hill and Sullivan.—*A. D. S.*

# THE DRIFT OF THINGS

. . . as followed by EDWARD H. ROBIE

## Income Taxes, Depreciation, And Your Annual Dues

This is the time of year when most of us are concerned with making out our income tax returns. AIME members should remember that dues paid to the Institute, and personal expenses incurred in attending meetings, together with professional engineers' license fees, may be deducted from gross income as business expenses, should one be engaged in making his living from his profession. Otherwise, dues, and voluntary contributions as well, can be deducted from income as a contribution made to a nonprofit scientific society. In either case, for the average person making between $5,000 and $10,000 a year and thus subject to the 22 per cent tax, a saving of a little over $3 out of the $15 annual dues is made. This brings the net out-of-pocket expense to a member for his Institute dues to about $12 instead of $15. A further saving of about sixty cents is made in the New York State income tax, and variable amounts by members in other states having an income tax. Thus regular membership in the AIME actually costs one living in New York about $11 instead of $15 a year.

Further, this $11 or $12 is in depreciated dollars. The 1939 or 1940 dollar is now worth about 59 cents according to the price index of the Department of Labor, and most salaries have been adjusted, at least in major part, to reflect this condition. Thus the $11 figure reduces to $6.49 in terms of 1939-49 dollars, or the $12 figure to $7.08.

Some have argued that Institute dues have actually been raised because one formerly received monthly journals plus a volume of Transactions for his $15, and now the volume costs $3 extra. This is true, but the reasoning outlined above, showing that the real amount of the dues paid is about $7 instead of $15, is equally true.

## Is a Professor a Teacher or a Researcher or Both?

How much and what kind of research work should our educational institutions accept, and who should get the benefit of the results? Are our technical colleges becoming more interested in getting contracts for research work than in getting students? Questions such as these have aroused considerable controversy in the last few months, and some schools, particularly, have been severely criticized.

Undoubtedly, and for good reason, thinking men in the country have become much more research minded than in the past. Probably the greatest eye opener as to the value of research is what has been accomplished in the field of atomic energy. Then, since the war we have learned of the great emphasis being placed on research in Soviet Russia, and fear has been expressed that that country might thereby progress faster than we. Also, the conditions in Germany and England are not propitious for the fundamental research that used to be carried on in those countries, later to receive practical application in America.

So both the Government and private industry in the United States have embarked on research programs to a much greater extent than in the past. The colleges were awake to the situation, and, with a low return on their endowed funds and much higher operating costs, were badly in need of the increased income that could be secured from accepting research contracts. They had much equipment that could be used for research purposes; and they had the elements of a supervisory research staff. Some colleges set up whole new departments for this work, and went actively after contracts.

Opposition has naturally come from private research organizations, operating for profit, and from consulting engineers, who have long been opposed to competition from Government agencies and educational institutions. Such private organizations do have a considerable advantage, however, in their long experience in practical research work, as against the younger graduates and students who do most of the work at university research centers.

The point of view of the commercial research laboratory has been well expressed by our own Sam Tour writing in *Chemical and Engineering News* on "Industry-Sponsored University Research." Among the points he makes are that our colleges are supposed to furnish a supply of research workers to industry but instead are drying up the supply by absorbing their graduates and the graduates of other schools in educational-institution research programs. That this is abnormal, and that the colleges are not the "seats of learning" for research as popularly supposed, at least in the engineering field, he proves by quoting from a survey made by Engineers Joint Council. This showed that out of a total of about 36,000 graduate engineers only 4.7 per cent are in colleges and universities, 8 per cent are in the consulting field, and 32.6 per cent are employed by industry on design, research, and development work. But even though the colleges do use a much smaller number of graduates than does industry, nevertheless they do, and are capable of doing more, excellent research work.

Before World War I, says Mr. Tour, looking at the situation with an unapproving eye, colleges were seeking students. Today the emphasis is on millions of dollars' worth of research laboratories and research and development work, and little is heard of additional classrooms. Alumni are urged to contribute dollars and dollar contracts, not students, and the primary purpose of many a university today seems something other than being a place where students may get an education.

Colleges, he says, have an unfair advantage in this respect, because private corporations have to charge research facilities as capital investment, which must come from limited profits heavily taxed and surtaxed. Thus private research facilities will cost "two to five times" as much as if installed by "a so-called nonprofit institution or an institution of higher learning." And "not only have the higher educational institutions obtained all these marvelous, magnificent, and enormous increased facilities on a substantially zero-cost basis, [much being Government war surplus] but they have them from now on on a tax-exempt basis" and "in many cases, these institutions have tax money with which to maintain these increased facilities. . . . Industry, Government, and the citizenry itself of this country might well consider what is being done to the free enterprise system upon which our country is based by this new trend toward tax evasion by concentration of billions of dollars per year of contractual work in tax-exempt quasi-public institutions." This contractual research work, says Mr. Tour, is representing more than half of the gross income and expenditures of some institutions.

Too, the problem of patents arising from such research has become a major one. Mr. Tour feels that the results of university research are obtained in part at public expense, and should be available to the public and not held confidential to, or held as a monopoly by, private enterprise. The solution that he suggests for the problem is for the universities to discontinue research for private enterprise and concentrate on research for the public benefit.

In spite of such opinions as Mr. Tour expresses, we have no fear that private research organizations will be put out of business by competition in the universities. In many fields the schools simply cannot compete, and in spite of their lower costs, for the reasons Mr. Tour states, we think that private research organizations deliver more for the same price than do the universities. Further, private industry can always pay more and thus get outstanding researchers; university research staffs are notoriously underpaid. And lastly, with the enormous current demand for research, there should be enough work for every laboratory in the country. The universities are merely trying to help take care of the demand. But of course, they should not forget that they are expected to do a fairish amount of teaching too!

## More for Your Money?

For the first time in its 48-year history, the United States Steel Corp. has decided to "split up" its stock, issuing three new shares for one of the old. To be sure, it did practically the same thing back in 1927, only then it was called a "stock dividend," and one share became 1.4 shares. In either case the equity remains the same so the value of the shares declines by an equivalent amount. This practice of splitting up shares was quite popular during the boom decade following World War I. It is supposed to make shares "more attractive" to investors, though there might seem no reason why cheaper shares should have more appeal to any one unless he merely wanted to buy one or two shares. Certainly, it is just as easy and as rewarding to buy three shares of a $75 stock as nine shares of a $25 stock.

However, apparently the fact remains that by splitting up their stocks, corporations do seem to attract a larger number of buyers, even though the reasons therefor may be largely psychological. For instance, for some time to come U. S. Steel will sound like a bargain at $25, whereas it wouldn't at $75. Also, its price is likely to vary more, percentagewise. Variations in stock prices are commonly reported in the newspapers as so many points, with total disregard of the price of the stock. Obviously, an increase of two points in a stock that is selling for $4 is a mighty big jump in terms of its value, whereas in a $100 stock, it is only a two per cent increase. And yet a two per cent change in the price of a stock attracts just about the same amount of attention on the part of casual investors and traders whether it applies to a cheap stock or to an expensive one. Another reason why a cheap stock finds a wider market is because a buyer ordinarily likes to buy ten shares instead of three, if he only has a few hundred dollars to spare; or fifty shares instead of fifteen if he is a little better off; or preferably a hundred shares—the usual trading unit—if he can afford to.

We really know little about this whole subject, having bought less and less stocks the more and more money we made, until in recent years we have bought none at all, which does not necessarily imply that our income is now infinitely large. Thirty years or so ago it seemed like good fun to gamble on cheap mining stocks, but in the last few years it has been more soul-satisfying to acquire a small piece of real estate with a good view of the eternal hills of Westchester where our friends seem to like to drop in of a Saturday or Sunday. What little of the gambling instinct remains is fully satisfied by the remote possibility that oil may eventually be found underneath. Geologists tell us that this means that our gambling tendencies have totally vanished.

# Among the Student Associates

### University of New Hampshire

At the University of New Hampshire Student Chapter's November meeting, Robert "Shorty" Sange spoke on his experience last summer as a National Park guide in the Grand Tetons. His talk was illustrated with excellent Kodachrome slides, showing much of that range's structure, wild life, and scenic beauty. He discussed the methods and results of research he had done on temperatures at the bottom of the bergschrund of one of the glaciers—*Marston Chase, Corresponding Secretary.*

Gemology was the title of the talk given at the December open meeting of the UNH Student Chapter by M. J. Kassner, certified gemologist. Mr. Kasner told of the occurrence of gems, how to identify them, factors which determine their value, and numerous anecdotes drawn from many years of experience in this field. He displayed his extensive and beautiful collection of gem stones.—*Marston Chase, Corresponding Secretary.*

### University of California

Members of the University of California Mining Association are preparing for the future now. At their Nov. 3 meeting, Burdette A. Ogle, who recently returned to the University from the Union Oil Co. to complete his Ph.D., spoke about the problems of a young petroleum geologist and about projects with which he was associated while in industry. The following week, the Association conducted the student meeting of the San Francisco Section, AIME, with discussions on curricula for mineral industries students. At the Dec. 1 session, Durand A. Hall, who maintains a consulting office in San Francisco, addressed the student associates on "The Problems Confronting a Young Mining Engineer." Speaking from wide experience, Mr. Hall gave the advantages and disadvantages the graduate should consider before seeking a position with either a large or small company in either the domestic or foreign field.—*William W. Carder, Jr., Publicity Chairman.*

### Michigan College of Mining and Technology

If the MCMT Student Chapter's first 1948-49 meeting is typical of succeeding meetings, this year will be our most successful; for we started out with an attendance of 119 students, an all time record for the Chapter. Through the efforts of our "live wire" program and activities committee, a motion picture, furnished by the Calumet and Hecla Mining Co., entitled "From Ore to Finished Product," was shown. Also furthering our success are the new officers: Roger Chapman, President; Harry Toelle; Vice-President; Donald Avery, Treasurer; and James J. Walker, Secretary.—*James J. Walker, Secretary.*

### Missouri School of Mines

The Student Chapter of the Missouri School of Mines held its last 1948 meeting on Dec. 9. Leon Dupuy, who heads the Rolla division of the Bureau of Mines, was speaker of the evening. Mr. Dupuy explained some of the developments made in mineral lands during the recent war, and the methods of exploration used. To illustrate his talk, Mr. Dupuy ran off a two-reel movie. Although a football film and refreshments were also offered the 180 men present, it was evident that Mr. Dupuy's speech was the highlight of the evening—*Albert A. Jones, Secretary.*

### Oklahoma A&M College

The AIME's newest Affiliated Student Society has been formed at the Oklahoma A&M College, in Stillwater, in the name of the Petroleum Engineering Club. At the nascent Society's first meeting, on Nov. 17, officers were elected to serve for the remainder of the academic year. They are: Lewis Smith, President; Bob Brakey, Vice-President; James Brazell, Secretary; and J. W. Jackson, Treasurer. Professor Glen Lee Corrigan will supervise the Club's activities, as Faculty Sponsor.—*James E. Brazell, Secretary.*

### South Dakota School of Mines and Technology

The first two meetings of the Drill and Crucible Club, at the South Dakota School of Mines and Technology, provided members with a fair share of business, educational, and social activities. The Sept. 21 meeting was taken up by the election of new officers: Ralph Flow, President; Henry Hurley, Vice-President; Russell Gamberg, Secretary; and Edward Jacobson, Treasurer. At the second meeting, our guest speaker, Freemont Clark, gave an informative talk on lithium production in the Black Hills, and extended an invitation for a field trip to one of the local mines. The Club then retired to partake in a well planned social program that included refreshments.—*Russell Gamberg, Secretary.*

### University of Southern California

Thirty-five members attended the initial meeting of the AIME Student Chapter at the University of Southern California, on Oct. 26. The highlight of this session was a talk given by D. K. Weaver, drilling superintendent for Wilshire Oil Co. Mr. Weaver spoke on the difficulties encountered in directional drilling, and took examples from his own experience to illustrate his points.—*Robert W. Sandiford, Secretary.*

### Texas College of Mines and Metallurgy

A meeting of the Kidd Mining Club, the AIME Student Chapter at the Texas College of Mines and Metallurgy, was held Dec. 6. The members discussed a plan to arrange an information center on minerals, mines, etc., in the West Texas-New Mexico-Chihuahua area, since many of the College's students go on weekend and holiday expeditions in that district. The evening's program also featured a discussion of mining methods, by R. E. Lindberg, and a description of the mineralization of the Santa Eulalia and Los Lamentos areas in Chihuahua, by J. L. Albright. Specimens of the rare minerals that had been collected in those areas were passed among the group. After the talks, two students who had been in Chihuahua last summer, added several items.—*Louis W. Cope, President.*

# What Went on at Recent Local Section Meetings

| SECTION | DATE | PLACE | PRESIDING OFFICER | ATTENDANCE | SPEAKER, AFFILIATION, AND SUBJECT |
|---|---|---|---|---|---|
| Arizona, Ajo Subsection | Jan. 13 | Ajo | William Keener | 21 | Film, "Ore Testing," American Cyanamid Co. |
| Arizona | Dec. 7 | Pioneer Hotel, Tucson | P. D. I. Honeyman | 278 | Annual meeting. |
| Black Hills | Dec. 9 | South Dakota School of Mines, Rapid City | C. N. Kravig | 48 | Annual meeting. |
| Boston | Jan. 10 | Smith House, Cambridge | George P. Swift | 65 | W. E. Wrather, President, AIME, on Near East oil. E. H. Robie, Acting Secretary, AIME, on Institute affairs. |
| Carlsbad Potash | Jan. 20 | Carlsbad | J. P. Smith | 48 | Films, "Story of Gasoline," Bureau of Mines and Standard Oil Co. of Indiana; "Story of an Ore Sample," American Cyanamid Co. |
| Chicago | Dec. 1 | Chicago | H. A. Herder | 61 | George G. Ensign, Elgin National Watch Co., on the story of Elgiloy. |
| Chicago | Jan. 5 | Chicago | H. A. Herder | 63 | D. P. Barnard, IV, Standard Oil Co. of Indiana, on stretching the petroleum barrel. |
| Cleveland | Nov. 11 | Cleveland | | | H. P. Croft, vice-president in charge of development, Wheeling Bronze Casting Co., on types of casting. |
| Cleveland | Dec. 9 | Cleveland | | | Dan White, engineer, National Advisory Committee for Aeronautics, on heat treatment of steel. |
| Columbia | Jan. 7 | Davenport Hotel, Spokane | Howard P. Sherman | 31 | Film, "Deep Horizons," The Texas Co. |
| Columbia | Dec. 3 | Spokane | J. W. Melrose | 700 | W. L. Zeigler, general manager, Pend Oreille Mines and Metals Co., on Pend Oreille Mines and Metals Co. development program. |
| Connecticut | Dec. 14 | Hammond Metallurgical Laboratory, Yale University | Henry Burghoff | 50 | John Hollomon, physical metallurgist, General Electric Co., on deformation of metals. |
| Delta, Mississippi Subsection | Nov. 17 | Natchez | W. W. Ramseur | 65 | J. L. P. Campbell, Lane-Wells Co., on the gamma ray and neutron formation logging. |
| Detroit | Jan. 17 | Detroit | E. J. Dofter | | C. A. Siebert, University of Michigan, on thermodynamics as applied to physical metallurgy. |
| El Paso Metals | Jan. 12 | El Paso | | | Wilson H. Elkins, President, Texas College of Mines and Metallurgy, on educational background for professional life. |
| Gulf Coast | Oct. 13 | Houston Club | George L. Nye | 140 | W. E. Wrather, President, AIME, on aspects of our future mineral supplies. |
| Gulf Coast | Nov. 16 | Y.M.C.A., Houston | George L. Nye | 92 | Walter Rogers, Gulf Oil Corp., on oil and subsurface corrosion of well equipment. |
| Gulf Coast | Dec. 21 | Y.M.C.A., Houston | George L. Nye | 68 | Edgar Kraus, Atlantic Refining Co., on allocation of production among pools and within pools. |
| Gulf Coast | Jan. 18 | Y.M.C.A., Houston | George L. Nye | 113 | Paul Weaver, Gulf Oil Corp., on water supply problems for mining and oil in Texas. |
| Kansas | Oct. 20 | Broadview Hotel, Wichita | V. J. Mercier | 55 | George Paschke, Kansas State Corp. Comm., on the engineer and the State Corp. Comm. |
| Kansas | Dec. 17 | Broadview Hotel, Wichita | V. J. Mercier | 56 | Martin E. True, Humble Oil and Refining Co., on semi-automatic power-operated drilling machinery. |
| Mid-Continent | Jan. 10 | Tulsa | John P. Hammond | 35 | G. C. MacDonald, Gulf Oil Corp., on transportation of bit cuttings in a rotary drilled well. |
| Minnesota | Jan. 17 | Duluth | E. P. Scallon | 362 | Joint meeting with University of Minnesota Annual Mining Symposium. |
| Montana | Jan. 25 | Butte | Hollis McCrea | 62 | E. W. Felegy, Bureau of Mines, on voice communication by radio through soil and strata. |
| New York | Jan. 20 | Mining Club, NYC | Thomas G. Moore | 88 | T. B. Ford, The Dorr Co., on conditions in the Far East from an engineer's viewpoint. |
| Oklahoma City | Nov. 17 | Oklahoma City | R. L. Beams | 60 | Henry Schaefer, Stanolind Oil and Gas Co., on porosity in limestones and sandstones. |
| Oklahoma City | Dec. 16 | Oklahoma City | R. J. Beams | | A. W. Walker, University of Tulsa, on squeeze cementing. |
| Oklahoma City | Jan. 18 | Oklahoma City | R. J. Beams | 46 | R. H. McClemore, Welex Jet Service, Inc., on jet perforating. |
| San Francisco | Nov. 10 | Engineers Club | W. W. Mein, Jr. | 85 | Joint meeting with student group. Discussion program presented by University of California Mining Association. |
| San Francisco | Dec. 8 | Engineers Club | W. W. Mein, Jr. | 113 | Annual reminiscence meeting. |
| Southern California, Metals Group | Dec. 6 | Los Angeles | W. A. Saylor | 39 | Film, "Development of Water, the Real Gold of California," Consolidated Steel Corp. |
| Southwestern New Mexico | Jan. 12 | Silver City | | | Business meeting. |

# News of AIME Members

E. H. Robie

At the first meeting of the new Board of Directors in San Francisco, on Feb. 16, **Edward H. Robie** was elected Secretary of AIME for the next Institute year, an action that will undoubtedly go down in the history of the Institute as one of the wisest and most foresighted ever taken by that governing body.

Educated as a chemical engineer and with a background of eight years in extraction metallurgy and twelve years on the editorial staff of *Engineering and Mining Journal* and of other mining publications, Ed, as he is known to his thousands of friends (he has no enemies), was employed by the Institute in 1931 as Assistant Secretary and Editor of *Mining and Metallurgy*. It was a fortunate choice for AIME; fortified by a broad perspective on all phases of the mineral industries, possessing an unusual amount of common sense, an innate ability to like people and to get along with them no matter how they stand in the scheme of things, Ed has during his service with the Institute played a major role in its progress from a society with 7800 members and four divisions and a publication and divisional budget of $87,000 in 1931 to a society with nearly 20,000 members, almost entirely divisionalized, and a publication and divisional budget of nearly $275,000 today.

We have known the new Secretary for nearly twenty years and we have worked closely with him for a part of that time, long enough to come to admire his executive ability, his friendly personality, and especially his well-developed sense of fair play—a valuable and not too common trait in these troubled times. AIME is to be congratulated.—*FTS.*

**Hubert R. Banks,** superintendent of the Sullivan concentrator at Chapman Camp, B. C., and **Desmond F. Kidd,** consulting mining geologist of Vancouver, were recently elected chairman and vice-chairman, respectively, of the British Columbia section of the Canadian Institute of Mining and Metallurgy. At the Toronto Branch of the Institute, **Charles C. Huston,** chief engineer of Hacassa Mines Ltd., Toronto, was elected vice-chairman.

**Charles B. Baton,** Greensburg-Connellsville Coal and Coke Co., **Henry F. Hebley,** Pittsburgh Coal Co., and **J. B. Morrow,** Pittsburgh Coal Co., have been appointed to the technical advisory committee for the Research Fellowship of the Western Pennsylvania Coal Operators Assn. The Fellowship, which was established at Mellon Institute in January, covers scientific studies of the causes, prevention, and control of coal-refuse fires, and of acid generation in coal-waste piles.

**F. Bellamy** is general manager of Singareni Collieries Co., Ltd., and receives his mail at Singareni P. O., N. S. Rly., Deccan, India.

**C. H. Benedict** retired as chief metallurgist for the Calumet & Hecla Consolidated Copper Co. last December, rounding out fifty years of continuous service with the company.

**Weston Bourret** has changed his residence from Scarsdale, N. Y., to 1107 San Pasqual St., Pasadena 5, Calif. He is with the exploration department of the Kennecott Copper Corp., in New York City.

**L. D. Briden,** who was with the Montreal Engineering Co., Montreal, Que., has gone to La Paz, Bolivia, as resident construction engineer for the Bolivian Power Co. He is addressed in care of the Company, Casilla 353, La Paz.

**Douglas C. Brockie** is a geologist for Eagle-Picher de Mexico, and can be reached in care of Minas de Iguala, Parral, Chihuahua, Mexico.

**Douglas W. Brown,** formerly with the Idaho Power Co., has become a mining engineer for the Hecla Mining Co., Box 320, Burke, Idaho.

**Sherman R. Burdick** has journeyed from California and established residence at Erwin, Tenn.; his mail goes to P. O. Box 175.

**R. J. Burmeister,** formerly vice-president of the Raleigh Coal & Coke Co., has been made president of the organization. **Ellsworth H. Shriver,** former assistant general manager, was named vice-president and general manager.

**H. A. Cochran,** who was H. M. Chief Inspector of Mines for Nigeria, is now divisional manager of the minerals division of the Colonial Development Corp. His business address is 33 Dover St., London, W.1., England.

**John J. Collins,** mining geologist, U. S. Geological Survey, Washington, D. C., returned to the States in February after completing assignments with the Corps of Engineers in the Western Pacific. His major activity was a study of the Japanese copper resources, production, and trade for the Natural Resources Section, GHQ, SCAP. Other assignments covered the mineral resources of the Yap Islands, the Fukui earthquake, coal production in Japan in 1945, and military geology studies of Japan and Okinawa.

**Howard E. Ames** has left his research engineering work in New York to join up with the New Jersey Zinc Co. at Gilman, Colo.

**Wilbur J. Cook** is mine superintendent for Patino Mines and Enterprises Cons., Siglo XX, Llallagua, Bolivia. He was with Cia. Minera de Oruro, Oruro, Bolivia.

**Alfred E. Copeland** is working as a mining engineer for the Clinchfield Coal Corp., Dante, Va.

**A. V. Corlett** resigned as manager of the Normetal Mining Corp., Dupuy, Que., to become professor of mining engineering at Queen's University, Kingston, Ont.

**Percy G. Cowin** writes that effective Jan. 1 the corporate name of Salmon & Cowin, Inc., mining engineers and contractors, was changed to Cowin & Co., Inc., mining engineers and contractors. There will be no change in policy, personnel, or service. The Company's address is 930 Second Ave. N., Birmingham, Ala.

**Daniel R. Croswell, Jr.,** who had been a student at the University of Minnesota, is working for the Kennecott Copper Corp., Ruth, Nev.

**Lucien Eaton** of Pierce Management, Scranton, Pa., is now doing consulting work for EtiBank, the Turkish Government agency, and working with **Fred G. Koper.**

**Reinhart P. Ehrlich** has taken the job of metallurgist with United Keno Hill Mines Ltd., Mayo, Y. T. He used to work for Kerr-Addison Gold Mines.

**Thomas R. Goedicke,** who had been a student at North Carolina State College, is an engineer and geophysicist with Sherwin F. Kelly Geophysical Services, Wilmington, Del.

**Irving Cary Falk** is now employed by the National Lead Co. as a junior mining engineer and surveyor at the MacIntyre Development, Tahawus, N. Y. He went to the world's largest titanium mine after graduating from the Missouri School of Mines last summer.

**Franklin Farley** was re-elected to the office of vice-president in charge of the phosphate division, of International Minerals and Chemical Corp., at the annual stockholders' meeting held in Chicago.

**George J. Featherstone, Jr.,** formerly of Elmsford, N. Y., is now living at 47 N. Seminary St., Madisonville, Ky. There, in the western Kentucky coal and limestone area, Mr. Featherstone is representing the explosives department of American Cyanamid Co.

**Douglas H. Fenske** graduated with a B.S. degree in metallurgical engineering from the Michigan College of Mining and Technology last August. He is now located with the International Minerals and Chemical Corp. at Mulberry, Fla., as a research engineer in the wet separations section of the ore dressing research laboratory.

R. C. Ferguson

**R. C. Ferguson** has been appointed North Central district manager of the Hardinge Co. with headquarters at 8th Ave. E. and Howard St., Hibbing, Minn. This is a new outlet for the Company. Mr. Ferguson has been with Hardinge since his graduation from Michigan College of Mining and Technology in 1925, his first assignment being in the engineering department at York, Pa. In 1937 he transferred to service and development work, and in 1946 spent part of his time in sales and process development assignments on the Minnesota iron range, a task which now occupies his full time. He has been developing and testing Hardinge grinding, classifying, and concentrating equipment for iron ore processing.

**Avery H. Reed, Jr.,** informs us that he's now employed as a mining engineer with the Bureau of Mines. Consequently, he's changed his address and is now at Box L, University, Ala.

**Robert Fleischman** has resigned as geologist of the Bureau of Mineral Resources, Canberra City, A.C.T., Australia, and has joined a commercial firm in Sydney as their technical representative for Australia, New Zealand, and the Islands, in the purchase of ores, concentrates, and scrap for export overseas. His address is 8 Hopefield, 25 Guilfoyle Ave., Double Bay, Sydney, Australia.

**John J. Flynn, Jr.,** who joined the Atlas Powder Co. in New York City after completing his courses at the Colorado School of Mines, has returned to Colorado to study law at Denver University. He resides at 1009 Jackson St., Denver.

**Edwin A. Friedman,** general superintendent of the Oliver Iron Mining Co. on the western Mesabi iron range, has been elected president of the Engineers' Club of Northern Minnesota.

**Andrew J. Gaber** has been made research engineer of the Nelson L. Davis Co., Chicago. He had been manager of the Terre Haute office of the Commercial Testing and Engineering Co. and prior to that was plant control chemist at the Champion No. 1 coal preparation plant of the Pittsburgh Coal Co.

**R. F. Goodwin** is now president of the Asarco Exploration Co. of Canada, Ltd., a newly-formed subsidiary of the American Smelting and Refining Co.

**Wesley P. Goss** has been named vice-president and general manager of both the Magma Copper Co. and the San Manuel Copper Corp., operating in Arizona.

**Irene Klein** and **E. H. Sharp** were married on Jan. 15, as we told you in the January issue. To clear up any possible question, Mrs. Sharp will continue to work at AIME headquarters and hopes to see many of her old friends before too long and to make many new ones.

C. E. Osborn

**C. E. Osborn** recently joined the staff of the Western Machinery Co. as a metallurgical engineer for the new equipment division. His assignment will keep him in the San Francisco office most of the time so the Osborns sold their Denver home and purchased one at 6036 Outlook Ave., Oakland, Calif. Mr. Osborn writes that he tries to attend the weekly luncheon meetings of the San Francisco Section at the Engineers Club, where they would like to see more visitors when they are in the area.

**Donald L. Graf,** who was an assistant in the geology department at Columbia University, has moved to Urbana, Ill., to take the job of associate geologist with the Illinois Geological Survey.

Clarence H. Hall

**Clarence H. Hall** is at his home at 1200 Strand, Manhattan Beach, Calif., recuperating from an illness contracted at Cia. Republica de Panama where he was general manager of Capira Mines Corp. Before his departure for Panama in 1947 he was chief engineer of the general mining department of the U. S. Vanadium Corp.

**Leroy J. Harrington** has been transferred by American Cyanamid Co. from its Little Rock, Ark., plant to the one in Chattanooga, Tenn.

**Arthur E. Henschen,** after finishing his studies at the University of Wisconsin, is working as salesman for the Aluminum Co. of America, Oliver Bldg., Pittsburgh.

**Whipple Jacobs** has transferred from the presidency of Belden Mfg. Co. to the presidency of Phelps Dodge Copper Products Corp.

**Fred D. Kay** has been appointed vice-president of the International Titanium Corp., of New York City.

**Rowland King,** of Spokane, Wash., has been re-elected president of the Northwest Mining Association.

**Otis A. Kittle** has dropped his exploration activities in Nevada, to be on hand at his tungsten mine in Bishop, Calif. He is addressed at P. O. Box 478, Bishop.

**R. Knobler** has been transferred to Oruro, Bolivia, as chief metallurgist in charge of the newly reopened experiment station of M. Hochschild, SAMI, where all ores from all mines of the Hochschild group in Bolivia are tested.

**William N. Laval,** formerly a student at the University of Washington, is now employed as a geologist with the USGS on the Colorado Plateau project. He may be addressed at 1440 Grand Ave., Grand Junction, Colo.

**Solomon Lieb,** general superintendent of the Bolivian Tin and Tungsten Mines Corp. in Bolivia, is at present in New York and can be reached at 21 Sherman, New York City 34.

**Plato Malozemoff,** of the Newmont Copper Co., is now back in New York City after a short stay in Superior, Ariz., where he did some work for the Magma Copper Co.

**James D. McClintock** has been working in the South Pacific area since last spring when he was assigned to the U. S. Philippine War Damage Commission. His mailing address is PWDC-APO 900, care of Post Master, San Francisco, Calif.

**Hugh E. McCray,** who had been operating the Burro Chief fluorspar mine in Tyrone, N. Mex., recently leased two adjoining fluorspar properties in the Cook's Peak mining district, around Denning.

**John B. McIntyre,** of Portland, Oreg., is temporarily employed in Washington, D. C. For the time being his residence is 3420 Patterson St. N.W., Washington 15.

Dale L. Pitt

**Dale L. Pitt,** prominent mine operator and executive, has been elected president of the Mining Association of British Columbia. For many years associated with the American Smelting and Refining Co. both in British Columbia and in Australia, he is one of those noteworthy citizens of the States who has made major contributions to the advancement of mining in Canada. Taking over his office as president, Mr. Pitt emphasized that it is the intention of the Association to continue with vigor and determination its established policy of advancing the best interests of mining in British Columbia. The continuation and expansion of the important contribution made by the mining industry to the Canadian economy is a matter of interest and concern to all and a fundamental objective of the Association.

**D. D. Moffat,** vice-president and general manager of the Utah division of the Kennecott Copper Corp., and **J. D. Shilling,** assistant general manager, resigned their posts the end of last year. Utah copper division operations now come under the general supervision of **J. C. Kinnear,** vice-president, who was in charge of operations in Arizona, Nevada, and New Mexico. **Louis Buchman** has succeeded Mr. Moffat as general manager of the Utah division and **E. W. Engelmann** is assistant general manager, succeeding Mr. Shilling.

**Morris Mielke** is working for the Oliver Iron Mining Co. at the research laboratory, 4832 Grand Ave., Duluth, Minn.

**Robert B. Mills** has returned to the University of Washington, after a brief absence in Kellogg, Idaho, to complete the work necessary for his degree, which he expects to receive in June.

**Frank W. Millsaps,** who was with the Magma Copper Co., Superior, Ariz., has gone half way around the world to work as a chemist for the Saudi Arabian Mining Syndicate, Jeddah, Saudi Arabia.

**Jack E. Morris** is working as a geologist for the Sloss-Sheffield Steel and Iron Co., Rt. 1, Munford, Ala.

**A. W. Ness** writes from 2549 Simpson Ave., Salt Lake City, that he is once again in safety work, the most interesting business in the world, for the AS&R Co. mining branch. There is so much to do, so much that everyone can do in safety work, that one lifetime seems just too short. His impression is that the Company is really going into the accident reduction business on the same scale that it is producing base metals.

**H. A. Pearse,** who has been chief metallurgist of the Howe Sound Co., has been made vice-president in charge of metallurgy and construction. **Vinton H. Clarke** has been made executive mining engineer.

**Arthur F. Peterson** has been promoted from his position as general manager of raw materials properties, Bethlehem Steel Co., to that of vice-president in charge of the Company's mining division. Mr. Peterson, who has been with Bethlehem Steel since 1924, is the successor to the late **M. L. Jacobs.**

**James H. Pierce** has resumed his duties as president of Pierce Management, Inc., in Scranton, Pa. For a while, Mr. Pierce had been in China to help outline a mining program for the National Resources Commission of that country.

**Adolf Edwin Place,** consulting mining engineer of Boulder City, Nev., has taken over the management of the Soledad and Oter lead mines in the Sierra Las Damas of northeastern Chihuahua. These are held under lease by Cia. Minera Arados, the latter being the Mexican branch of the Sierra Las Damas Mines of Salt Lake City. Mr. Place's Mexican address is care of Chihuahua Foreign Club, Apartado 68, Chihuahua, Chih., Mexico.

**H. R. Plommer** is managing director of Canadian Collieries (Dunsmuir) Ltd., and all their subsidiary companies, Nanaimo, B. C.

**Russell S. Poor** joined the Oak Ridge Institute of Nuclear Studies, Oak Ridge, Tenn., as chairman of the University relations division in January. In his new post, Dr. Poor, who had been dean of the graduate school of Alabama Polytechnic Institute, will have charge of the graduate training and research participation programs two of the Oak Ridge Institute's most important activities. It is through these programs that the great research facilities at Oak Ridge are made available to American scientists. Many of the nuclear scientists of the future will be trained through these programs.

**Norman W. Pronger, Jr.,** since October has been employed by the U. S. Smelting Refining and Mining Co. at the Lark mine. Starting in as a mucker, he has recently been working as a drift miner.

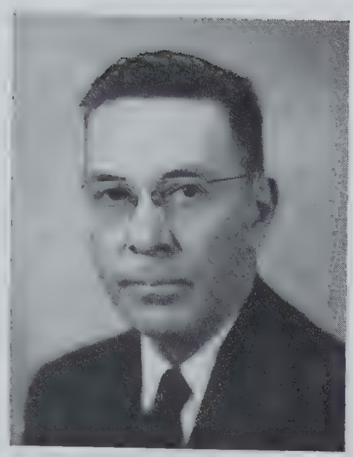
**John F. Provost** has been transferred by the New Jersey Zinc Co. from Franklin, N. J., to Jefferson City, Tenn.

**A. R. Reiser** was previously assistant plant manager of the National Lead Company's MacIntyre titanium operation at Tahawus, N. Y. He is now in New York City as assistant chairman of the Company's mining committee.

**Alfred L. Ransome,** who was supervising engineer with the Bureau of Mines' Metal Economics Branch in San Francisco, is now with the Bureau's Alaska branch in the same capacity. His address is now P. O. Box 2628, Juneau.

**W. G. Robinson,** formerly a student at the Colorado School of Mines, is now addressed in care of the Inland Steel Co., Marion, Ky.

**Oswald J. Ryan** is now addressed at the Australian Iron and Steel Collieries Ltd., P. O. Box 39, Wollongong, N. S. W., Australia.



D. R. Schooler

**D. R. Schooler,** formerly with the Paul Weir Consulting Engineering Co. of Chicago, has been appointed associate professor of mining engineering at the Missouri School of Mines and Metallurgy, Rolla.

**Alfred B. Sabin,** projects manager of the Western Knapp Engineering Co., has made an inspection trip to Idaho where the Company is building two plants for the Bradley Mining Co. The tungsten concentrator at the Ima mine is now in operation. The other plant, an antimony smelter at Stibnite, is scheduled for completion later in 1949.

**Richard D. Sandoe** has left the Simpson Creek Colliery Co., of New York City, and has joined the Western-Knapp Engineering Co., also in New York City.

**Carl W. Sawyer,** who at one time was with the King Island Scheelite N. L., Currie, King Island, Tasmania, is now addressed in care of the U. S. Vanadium Corp., Bishop, Calif.

**Edward P. Scallon,** who had been in charge of the land department of Butler Brothers iron mining interests, has opened an office at 137 E. 8th St., St. Paul, Minn., as a consulting mining engineer.

**Edgar Sengier,** executive director of the Union Miniere du Haut Katanga, has had a newly discovered radioactive mineral named for him. "Sengierite," which is a hydrous copper-uranium-vanadium mineral similar to carnotite, was found in the Belgian Congo and identified in the geology laboratories of Columbia University. Its name was decided upon as recognition of Mr. Sengier's efforts in directing mineral production in the Congo during the war.

**Floyd H. Shellenberger** is now employed as mine foreman for Helena Mines in the Bohemia district of Lane County, Oreg. His address is P. O. Box 466, Cottage Grove, Oreg.

**Jack E. Smedley,** formerly at the University of Idaho, is working as a paleontologist in the section of stratigraphy and paleontology of the U. S. Geological Survey, Washington 25, D. C.

**Francis M. Smith** has changed his residence from Ketchikan, Alaska, to Metaline Falls, Wash., where he is working as a shift boss with the Pend Oreille Mining and Milling Co.

**Ralph O. Smith** has given up his job as general sales manager of the Vulcan Iron Works to take over the presidency of the Wilkes-Barre Iron Mfg. Co. The firm is located at Hanover and Race Sts., Wilkes-Barre, Pa.

**R. N. Spencer,** formerly with the Bureau of Mines, is president of Chemical Lime, Inc., Palmer Bldg., Baker, Oreg.

Norman C. Stines

**Norman C. Stines** has transferred all his activities from placer gold mining in Alaska to base metal exploration in the States. During 1948 he spent several months in northern Churchill County, Nev., investigating the copper field in the Stillwater Range, east of Lovelock. During recent months he examined a lead-silver-zinc property in Pershing County, Nev., and as soon as the cold weather breaks, he expects to start mining and shipping operations from three old mines in that district. Headquarters will be in Winnemucca.

**Robert L. Squires** was graduated from the University of Illinois with a degree in geology, and is now employed as a sampler in the geology department of Day Mines Inc., Wallace, Idaho. Mr. Squires's residence is the Ryan Hotel in Wallace.

Ward Edinger

**L. P. Starck,** who holds a mining engineering degree from the University of British Columbia, has joined Canadian Exploration, Ltd., as assistant mill superintendent at the company's Emerald tungsten concentrator in Salmo, B. C. Before Mr. Starck assumed this job he was pursuing a graduate course of studies, at the University, which would lead to a master's degree in metallurgical engineering.

**C. H. E. Stewart** has been elected to the office of vice-president and general manager of Nicholson Mines, Ltd., Toronto, Ontario.

**Elbert D. Stewart** retired last fall from the Westinghouse Electric Corp., El Paso. He spent most of his professional life in Arizona, New Mexico, and Mexico, working with mining companies such as Phelps Dodge, Kennecott, and AS&R. Mail reaches him at 2709 Richmond, El Paso.

**Pisoot Sudasna,** after receiving his Engineer of Mines degree from the Colorado School of Mines, went to work with the Oliver Iron Mining Co. as a mining engineer. His address is P. O. Box 756, Hibbing, Minn.

**George L. Sullivan** is superintendent of the Wisconsin branch for the Calumet & Hecla Consolidated Copper Co. His address is Box 557, Shullsburg, Wis.

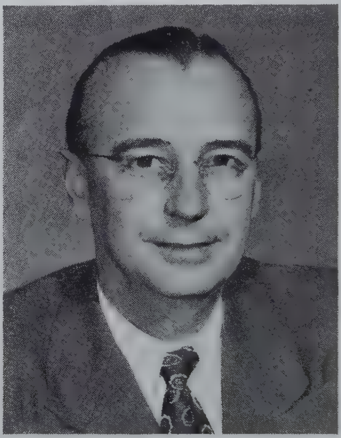
**Irvin L. Tailleur** is working as mining geologist for the International Nickel Co. of Canada. His address is 332 Nelson St., Sudbury, Ont.

**Donald S. Tedford,** of Columbus, N. Mex., is doing exploration work on the Royal John mine, in the Black Range district of the State.

**H. E. Treichler** has been named vice-president and general manager of the Texas Gulf Sulphur Co. He has been associated with Texas Gulf for thirty years and has served as its general manager since 1930. A real veteran and pioneer of the American sulphur industry. Mr. Treichler has been active in the industry's Gulf coastal development since 1918.

**Samuel Valencia** has received an appointment as research assistant in the department of metallurgy at MIT, Cambridge, Mass. This assistantship will enable him at the same time to undertake studies for obtaining his master's degree in metallurgy.

**Frank H. Wagner,** his wife and daughter, left Lima, Peru, the latter part of January to return to their home in Wilkes-Barre, Pa. Mr. Wagner recently resigned from the Banco Minero del Peru and will resume his consulting engineering practice.



E. O. Buck

**Peter Warhol,** who was development engineer with Butler Brothers, is now addressed in care of the Leo Butler Construction Co., 8416 Georgia Ave., Silver Spring, Md.

**Sherman A. White** is general superintendent of Cia. Minera de Oaxaca. This is an antimony property located in the State of Oaxaca, Mexico, and owned by the National Lead Co. Mines, both underground and open pit, and mill are located at Los Tejocotes.

**Ernest Wittenau,** manager of Phelps Dodge Corp.'s New Cornelia branch, has retired from active duty in Ajo, as of Dec. 1. With his resignation, Mr. Wittenau ended 33 years of service with Phelps Dodge, in various positions at the company's Ajo and Morenci mines. Among the accomplishments that the company can credit to Mr. Wittenau's direction are the development of the open-pit mine at Morenci, the erection of concentrating and smelting facilities there, and the electrification of the haulage system at the Ajo open-pit.

**Thomas E. B. Young,** a member of the National Coal Board, living in Chesterfield, England, was granted a knighthood recently. **Colonel W. C. Devereux,** chairman of International Alloys, Ltd., was awarded the Commander (of the Order) of the British Empire.

## • In Petroleum Circles

**Fred E. Abbott, Jr.,** now receives mail at the Arabian American Oil Co., Dhahran, Saudi Arabia. Mr. Abbott holds the position of chief petroleum engineer with the Company.

**Harry D. Aggers,** as district production foreman with the Union Oil Co. of California, has been transferred by the Company from Orcutt to Compton. His new address is 17810 S. Central, Compton, Calif.

**Johnson Bennett** is fields manager for the Basrah Petroleum Co., Basrah, Iraq. He had been with the Iraq Petroleum Co.

**James W. Bowler,** formerly with the Colombian Petroleum Co. in Cucuta, Colombia, has moved to Cairo, Egypt, where he is working for Socony-Vacuum Oil Co. His new address is 62 Shariah Ibrahim Pasha, Cairo.

**E. O. Buck** is a vice-president of the National Bank of Commerce of Houston, Texas. He had been manager of the Bank's oil loan department for a year, going there from his post as southern manager of the Rowan Drilling Co. During the war Mr. Buck was director of production for the PAW in District 3.

**Allan B. Cole,** formerly with Stacey Dresser Engineering of Cleveland, Ohio, is now in Caracas, Venezuela, as gas engineer for the Socony-Vacuum Oil Co.

**Glen Lee Corrigan,** who was an associate professor of mechanical engineering at Oklahoma A&M College, is now located at the Louisiana Polytechnic Institute where he is a professor and head of the department of petroleum engineering.

**E. G. "Ty" Dahlgren** resigned as assistant secretary of the Interstate Oil Compact Commission, effective Jan. 1, to become a consultant with offices in the Braniff Bldg., Oklahoma City, Okla. A 1929 geology graduate of the University of Wisconsin, Mr. Dahlgren has served with the Indian Territory Illuminating Oil Co., the Oklahoma City Producers' Assn., the Oklahoma Corporation Commission, and the Kansas State Corporation Commission. By 1939 he was in Washington, D. C., with the Securities and Exchange Commission and in 1941 became identified with the PAW. In January, 1942, he resigned to become technical secretary of the research and co-ordinating committee of the Interstate Oil Compact Commission at Oklahoma City.

**H. E. Dixon**, after receiving his degree from Texas A&M last August, took a job with the Cities Service Oil Co., Bartlesville, Okla. He has been working in the Oklahoma City field with the production division.

**K. L. Dominy**, formerly a drilling engineer with the Atlantic Refining Co. at Magnolia, Ark., is now petroleum engineer for the Root Petroleum Co. located in El Dorado, Ark.

**John A. Downing**, until recently a Montana School of Mines student, is working for the Bear Oil Co., Edmonton, Alta., as a geologist.

**Reginald J. Duran** has been promoted to district superintendent for the Baroid Sales Division over the Northern Louisiana and Southern Arkansas district and is now living at 1804 Magnolia Ave., Shreveport, La.

**Ward Edinger**, co-owner of Production Engineering Laboratories, Oklahoma City, Okla., has done all the engineering work in the recently unitized East Edmond field in Oklahoma County, Okla.

**Tell Ertl** has become associated with the Union Oil Co. of California, continuing his work on oil-shale mining.

**Robert J. Goodwin** graduated from the West Virginia University School of Mines last June with a degree in mining plus petroleum engineering option. He went to work with the Ohio Oil Co. of Findlay, Ohio, as an assistant district petroleum engineer in the East Texas oil field. His address is Henderson, Texas.

**Robert L. Hoss**, who had been working with the Kewanee Oil Co. at Tulsa, is now in Houston, working for the Humble Oil and Refining Co.

**Joseph B. Humber**, president of the H & H Engineering Co., has moved to 4016 Huey St., Houston, Texas.

**Godfrey F. Kaufmann** conducts his activities as geophysical research co-ordinator for Standard-Vacuum Oil Co. from room 1556, instead of room 643, at 26 Broadway, New York City.

**Albert F. Lager** is petroleum attache at the U. S. Embassy in Bogota, Colombia.

E. G. "Ty" Dahlgren

**Warren K. Lewis**, emeritus professor of chemical engineering at MIT, has been unanimously selected to receive the 1949 gold medal of the American Institute of Chemists. Presentation will be made at the Institute's annual meeting in Chicago, May 6 and 7. Dr. Lewis, noted for his contributions to research, particularly in the fields of petroleum and leather manufacture, has been on the MIT staff almost entirely since his graduation from there in 1905. During World War II, Dr. Lewis served as acting executive officer of the department of chemical engineering at MIT, and handled all the administrative work in connection with war research projects and war training courses in that department. He was also consultant with the National Defense Research Committee of the Office of Scientific Research and Development on chemical warfare problems, and served on special committees for the Manhattan District.

**Joseph B. Lovejoy** has left the Gulf Oil Corp. to take on the work of the vice-president in charge of exploration, for S. W. Richardson, Inc. The company's address is 2105 Fort Worth National Bank Bldg., Fort Worth, Texas.

**Paul B. Mallory**, who has worked for the Pantepec Oil Co. in Venezuela, is now in Pasadena, Calif., a petroleum engineer with Oil Properties Consultants, Inc.

**R. C. McCutchan** has left Breckenridge, Texas, and taken up residence in Odessa, Texas. He is working for Phillips Petroleum Co. as a petroleum engineer.

**Eugene McDermott** has been elected chairman of the board of Geophysical Service Inc., Dallas, Texas. In this position, Mr. McDermott devotes all his time to the direction of the company's enlarged program of research on fundamental exploration problems.

**Thomas V. Moore** and **Jerome Strauss** received Certificates of Appreciation last December from the Army and Navy for their outstanding contributions to the work of the Office of Scientific Research and Development during World War II.

**John O. Nigra** has taken the post of head of the petroleum technology department at Orange Coast College, Costa Mesa, Calif., and is no longer at Pasadena City College, where he had been on the faculty as instructor in geology since 1946.

**Robert L. Pott**, formerly a student at the Montana School of Mines, is now with the Sinclair Wyoming Oil Co., Box 1809, Casper, Wyo.

Ernest R. Lilley

**Ernest R. Lilley** has been elected vice-president in charge of the oil and gas division of the Great Lakes Carbon Corp. For several years manager of the division, Dr. Lilley continues as its chief geologist with headquarters at the New York office. Prior to World War II, Dr. Lilley was professor of economic geology and chairman of the department of geology of New York University, and during hostilities served PAW as chief analyst of the division of reserves.

**Helen Redmond** was graduated from the University of Cincinnati last year with the degree of B.S. in metallurgical engineering. At present she is employed as a metallurgist by the Buckeye Foundry Co., 2800 Beekman St., Cincinnati 25, Ohio.

**John R. Rickman**, who was with the Atlantic Refining Co., is now a petroleum engineer with James A. Lewis Engineering, Evansville, Ind., consultants primarily on secondary recovery operations.

**Arthur C. Stults** is consulting engineer and partner in the firm King-Latham-Stults & Co., valuation and consulting, 6617 Snider Plaza, Dallas, Texas.

**T. J. Tighe,** former Texas A&M student, is working with Dowell Incorporated as service engineer in the New Orleans district. His work is oil and gas well chemical service. Mail reaches him at 306 Morningside Dr., Houma, La.

**Lucius W. Waterman** has resigned from Geophysical Service Inc., Dallas, Texas, and taken up residence at 1130 Punta Gorda, Santa Barbara, Calif.

**Marsh S. Watson, Jr.,** is attending the University of Oklahoma School of Petroleum Engineering on a Shell Oil Co. Fellowship established for candidates working toward a master's degree in petroleum engineering. He attended Texas A&M and the New Mexico School of Mines and has worked as petroleum engineer for the Continental Oil Co. in New Mexico, and the Texas Petroleum Co. in Venezuela.

**Ben F. Zwick** has left the Standard Oil Co. of N. J. to assume the vice-presidency of the Husky Refining Co., of Cody, Wyo. He is in charge of the Company's Canadian operations, Husky Oil and Refining Ltd., at Calgary, Alta.

## • In the Metals Divisions

**Lee H. Allen** recently returned to the States after studying abroad, and is now working for Hickman, Williams & Co., 1203 Ford Bldg., Detroit, Mich.

**Ralph B. Adair** became chief engineer at the minerals research laboratory of North Carolina State College, Asheville, N. C., last December. He had been with the Tennessee Copper Co.

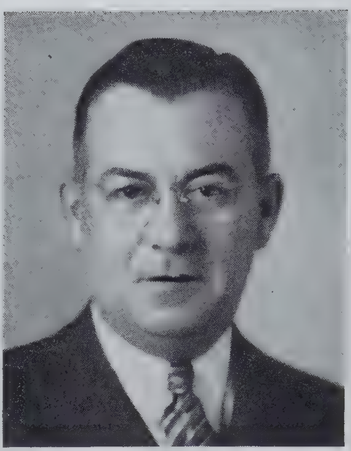
**J. D. Allan** received his Ph.D. degree in geology from MIT last year and has the post of chief geologist, mines branch, Manitoba Department of Mines and Natural Resources, Winnipeg.

**John S. Babcock,** who was at Pioneer, B C., working for Pioneer Gold Mines, has gone to Hanover, N. Mex., with the Empire Zinc Mining Co.

**John E. Bemis,** recent Michigan College of Mining and Technology graduate, is working in the engineering department of The M. A. Hanna Co., Hibbing, Minn.

**Karnig A. Berberian** is now on the staff of the metals research laboratory at the University of Vermont and a part-time instructor in the mechanical engineering department.

**Edmund W. Booker** has been made superintendent of the Gorgas mine of the Alabama Power Co., Gorgas, Ala.



William E. Brewster

**William E. Brewster** retired on January 1 as manager of operations for the International Harvester Company's steel division, thus ending an outstanding 38-year career in the industry. Mr. Brewster's retirement was marked at a party given in Chicago on Jan. 19, attended by more than 260 representatives of steel and other industries in the United States and Canada. Organized by Mr. Brewster's friends at the Wisconsin steel works, the party was intended to be a small gathering, but mushroomed rapidly as out-of-town invitations were snapped up. A representative cross-section of the entire steel industry attended and presented the Guest of Honor with a set of matched luggage and a scroll, signed by those who attended. A Yale graduate with a B.S. degree in chemistry, Mr. Brewster went to work for Wisconsin Steel shortly after graduation in 1910, starting as a billet dock laborer. By 1918 he was assistant superintendent of blast furnaces, and ten years later became head of that department. In 1945 he became general superintendent, and two years later began managing the company's steel mill, Kentucky coal mines, ore boats, and various iron ore projects. Mr. Brewster plans "to travel extensively through the southwest," but 8918 Hamilton Ave., Chicago, is an address which will reach him.

**V. A. Brussolo** called at AIME headquarters at the end of December, but expected to return to the Philippines shortly, where he is consultant to the Soriano interests in Manila. He expected to spend considerable time early in 1949 in Japan, Indo-China, and other eastern Asiatic areas. He reports mining slowly recovering in the Philippines, though few of the gold mines find conditions attractive for operating, with low labor productivity, high labor costs, and a comparatively modest price for the product. There is some activity in iron, chromite, and manganese mining.

**James H. Cazier,** who had been with the RFC, has become superintendent of mines for the Goodwin Mining Co., Bagdad, Ariz.

**Franklin Coolbaugh** has been made assistant general superintendent of the Climax Molybdenum Co., Climax, Colo. **W. K. McGlothlin** has been promoted to mine superintendent and **Willis Wamsley** to assistant mine superintendent.

**Anthony L. Cooper,** who has been a student at the University of Kansas, is working as an aeronautical research scientist and metallurgist for the National Advisory Committee for Aeronautics, doing research on high-temperature materials for flight propulsion systems. He receives mail at 738 Longfellow Drive, Berea, Ohio.

**A. O. Crobaugh,** formerly with the Ingersoll-Rand Co., is a metallurgist in the rocket department, propeller division, Curtiss-Wright Corp., Caldwell, N. J.

**P. S. Cross,** former manager of Miles (Red Lake) Mines Ltd., has taken over as geologist at Renabie Mines Ltd., Missanabie, Ont.

**C. C. Cushwa,** former manager of the Spring Hill Gold Mines, is engineer at the Ancho Erie mine of the Ancho Erie Mining Co., operating north of Washington, Calif.

**Herbert P. Dickey** has the post of general superintendent of the Quebec Iron and Titanium Corp., 1522 Sherbrooke St. W., Montreal 25, Que.

**Clair M. Donovan** is plant engineer for the Wheeler-Van Label Co., Grand Rapids, Mich. Mail addressed to 1419 Sigsbee St. SE., Grand Rapids, reaches him.

**M. K. Drury,** assistant to the general manager of the Western smelting department of the American Smelting and Refining Co., has been transferred to the Company's New York office.

**R. Tracy Eddinger,** who had been studying at Ohio State, has joined the research department of the Pittsburgh Consolidation Coal Co., Library, Pa.

**Roland I. Erickson** is mining engineer for the Cleveland Cliffs Iron Co., Hibbing, Minn., and receives his mail at Box 242, Marble, Minn.

**Thorold Field** and **Orvil R. Whitaker,** consulting engineers of Duluth and Denver, respectively, have been appointed to the Atomic Energy Commission's Advisory Committee on Raw Materials. Mr. Field is associated chiefly with the Congdon Office of Duluth and with Case, Pomeroy & Co. of New York City, and is a director of the latter company. During the war he served as a consultant to the WPB. Mr. Whitaker has had an independent consulting practice in Denver since 1912. He has been engaged in professional work in Mexico, Central America, Canada, Cuba, and various parts of the States. Other members of the Advisory Committee on Raw Materials are: **Everette DeGolyer, Wilber Judson, Robert E. McConnell, Donald H. McLaughlin, Fred Searls, Jr.,** and **Clyde Williams.**

**Robert B. Freeman** has been made chief metallurgist at the Columbia Steel Co. of Pittsburg, Calif., succeeding **Gordon L. von Planck.** Mr. von Planck continues to serve Columbia in the capacity of metallurgical consultant.

**Alice D. Fischer** is now a junior metallurgist with the Argonne National Laboratories in Chicago. She can be reached at 6146 Kenwood, in the same city.

**Joseph B. Gillenwater** is superintendent of strip mining for the Bailey Construction Corp., Thomas, W. Va. He assumed this position last August, and his address is now Box 68, Thomas.

**William A. Griffith,** University of Idaho graduate, is now an instructor in metallurgy at MIT. He has moved from the MIT Graduate House to 81 Marion Street, Brookline, Mass.

**Kenneth L. Keating,** a native of Tahawus, N. Y., is now a student in the graduate division of the Missouri School of Mines at Rolla. He can be reached in care of Lester Huffman, RD 1, Rolla.

**Harmel A. Dawson,** who had been attending the Montana School of Mines, is employed at present as a metallurgist for the Combined Metals Reduction Co., Stockton, Utah.

**H. P. Gaw** has been made works metallurgist of the East works, metallurgy department, the Armco Steel Corp., Middletown, Ohio.

**Leonard W. Kates** was formerly a member of the staff of the Division of Industrial Co-operation at MIT and is now engaged by Sylvania Electric Products, Sylvania Center, Bayside, L. I., N. Y., as a development engineer.

**Walter A. Mucek,** formerly a student at the University of Illinois, is working as assistant metallurgist at the Howard Foundry, Chicago, and receives mail at 3446 N. Ruby St., Franklin Park, Ill.

**William B. Price,** who retired late in 1947 and was for many years chief chemist and metallurgist for the Scovill Mfg. Co., Waterbury, Conn., has been elected to honorary membership in the American Society for Testing Materials. A pioneer metallurgist in the brass industry, playing a large part in putting the industry on a sound scientific and technical basis, Mr. Price had been with Scovill since his graduation from the Sheffield Scientific School of Yale University in 1902.

**John Rae, Jr.,** was appointed, last December, joint managing director of McKechnie Bros. Ltd., new associated South African company, McKechnie Bros. South Africa (Pty.) Ltd., Gerniston, Transvaal. He sailed for his new position on the "Stirling Castle," together with his wife and family.

**C. A. Scharschu** has been appointed assistant technical director of the Allegheny Ludlum Steel Corp. **L. C. Hicks,** formerly associate director of research, has taken over Mr. Scharschu's post of director of research. Mr. Scharschu has been with the Corporation for twenty years, starting as chief metallurgist and director of research. He was previously employed by General Electric Co. Dr. Hicks has been with the research department since 1933.

Maurice W. Daugherty

**H. L. Smith** has been appointed to the newly created post of executive technical engineer of Federated Metals, division of the American Smelting and Refining Co. For the past ten years he has been an active field metallurgist, working with customers on development and production problems. In his new capacity he will be assisted by a staff of service engineers and foundry technicians who will aid him in broadening the services rendered by the Company to the nonferrous metalworking industry. Beginning as a chemist in the Pittsburgh plant of the Company 25 years ago, Mr. Smith has advanced through many responsible positions. His headquarters will remain at 615 Gross St., Pittsburgh.

**Walter O. Snelling,** consulting chemist and director of research of the Trojan Powder Co., Allentown, Pa., has been appointed to the Atomic Energy Commission's Advisory Committee on Raw Materials. The Committee is now composed of seven members with **D. H. McLaughlin,** president of the Homestake Mining Co., as chairman.

Kent R. Van Horn

**Kent R. Van Horn,** chief of the Cleveland branch of the research laboratories of the Aluminum Co. of America since November 1945, has been named an assistant director of research for the company. **Maurice W. Daugherty,** assistant chief of the Cleveland laboratories during the same period, succeeds Dr. Van Horn as chief. One of the nation's outstanding metallurgists, and an authority in the field of industrial X-ray, Dr. Van Horn remains in Cleveland, where he will continue to devote his talents to the improvement of Alcoa casting and forging processes and alloys, the special function of the Cleveland research division. Mr. Daugherty, similarly prominent in metallurgical circles and in research into the corrosion of light metals, will supervise laboratory staff work.

**George M. Snyder** has left his job as metallurgical contact representative for the Carnegie-Illinois Steel Corp., in Pittsburgh, to fill the position of executive metallurgist at the Woodings Verona Tool Works, in Oakmont, Pa.

**Erwin Sohn** is director of research for the National Sanitary Co., Salem, Ohio. He had been addressed in care of the American Radiator and Standard Sanitary Co., Louisville, Ky.

**John H. Spillane,** formerly with the Electro Metallurgical Sales Corp., in Chicago, is now the assistant manager of the Union Carbide and Carbon Corp.'s ore and metal division, in New York City.

**Milton E. Warren** graduated from the Colorado School of Mines with a degree in metallurgical engineering last September. He went to work for the Aluminum Co. of America in the metallurgical department of their Edgewater, N. J., works in October.

# Obituaries

Charles E. Locke

An Appreciation by C. R. Hayward

In many parts of the world there have been expressions of sorrow as word of the passing of Charlie Locke has arrived, for few men have had so many friends in so many countries.

Professor Locke was born in Milton, N. H., Aug. 29, 1874, and was graduated from MIT in 1896. He immediately became associated with Professor Robert H. Richards, first as a private assistant and then as a regular member of the staff of the MIT department of mining and metallurgy. He continued this connection until his retirement as Professor Emeritus. In addition he served as secretary of the MIT alumni association from 1930 until his death.

Although Professor Locke had a host of friends who were not MIT alumni, it was to Tech men that he was best known and in particular to the graduates in mining and metallurgy. As students these men received his special attentions in numerous ways and large numbers of them kept their contacts with him after graduation. He kept a personal file of their activities and took a real interest in their professional progress. Until a few years ago every graduate in mining and metallurgy, after starting his first job, received a letter from Professor Locke; in many cases this led to regular correspondence and warm friendship.

He took an unusual interest in AIME affairs and was a regular attendant at the Annual Meetings in New York. It is doubtful if any other school had his equal in informing students in mining, metallurgy, and geology regarding the importance of student membership and urging them to join. He saw to it that each student had an application blank and took some positive action on it in one way or another. More than any man on the MIT staff, he interested himself in the welfare of the Student Chapter.

There was something unusual about Charlie Locke's interest in his callers and correspondents. He was never perfunctory. He received innumerable letters, asking for all kinds of information, some of which could have been answered with a few sentences. But this was seldom done, instead a detailed reply was sent giving, in many cases, information it had taken him considerable time to collect. He always managed to insert a warmth and interest in his general correspondence which most of us reserve for a few intimate friends.

Professor Locke had a remarkable capacity for detail, an attribute which made him a good research man. He was also a good teacher, an excellent administrator, and a successful consultant in the ore dressing field but like Abou Ben Adhem of old he will be recorded first in that select company of those who loved their fellow men.

CHARLES ENZIAN (Member 1911), a consulting mining engineer and geologist of Wilkes-Barre and Hazleton, who had been associated with the anthracite and bituminous industries for fifty years, died on Dec. 7, after suffering a heart attack. The 71-year career thus ended had been concentrated, almost entirely, on the Pennsylvania coal fields. The first step taken by Mr. Enzian in that direction was at the age of 16, when he became an apprentice mine surveyor. Soon after though he left for Lehigh University, and there studied civil engineering with electives in mining and geology. In 1901, upon graduation with a C.E. degree, he returned to the field and was employed by various coal companies throughout Pennsylvania. He practised his profession in this manner until 1932 when he put it on more or less of a consulting basis.

Charles Enzian

WILLIAM HARVEY EMMONS (Member 1907), professor emeritus of geology and mineralogy at the University of Minnesota, died in Minneapolis on Nov. 5, at the age of 72. He had assumed his title four years ago when he retired from his position as head of the University's department of geology and mineralogy. Besides this pedagogic position, Dr. Emmons had also held that of director of the Minnesota Geological Survey (both since 1911) and that of associate editor on the *Journal of Geology*. Dr. Emmons was appointed to these responsible posts after but seven years of mining geology experience, with the USGS, which mainly concerned the metaliferous ore deposits of the Rocky Mountains. This work, in turn, followed his graduation in 1904 from the University of Chicago, with a Ph.D. degree.

GEORGE M. COLVOCORESSES (Member 1907), an outstanding authority in the field of mining and metallurgical engineering, passed away Dec. 14, in Phoenix, Ariz. Right up to that time, although he was almost seventy and had been in ill health the past five years, he remained active in his Phoenix consulting work. In the course of this work, Mr. Colvocoresses had examined and evaluated mining properties throughout the Southwest. That his judgment was highly regarded is evidenced by the fact that he was frequently called upon to testify as an expert witness in mining and metallurgical litigations, before Government commissions in Canada and the United States.

Getting the experience that led to his prestige was started in 1900, soon after his service in the Spanish American War and his graduation from Yale University. For twelve years Mr. Colvocoresses worked in various technical capacities all over the world for the International Nickel Co. and its subsidiaries, doing practically everything, from underground mining to metallurgical research, from the West Indies to New Caledonia. Then, between 1914 and 1930, he was engaged by Consolidated Arizona Smelting Co. and its successor, Southwest Metals Co.; his post was that of general manager. During this period he also was a consultant to numerous mining outfits in the Southwest. In 1930, when he left Southwest Metals Co., he set up the consulting practice he maintained until his death.

ROBERT W. HANDLEY (Member 1917), a metallurgical engineer formerly with the Union Mines Development Corp., passed away June 29, in Colorado, after a prolonged illness. Mr. Handley had only recently returned to Colorado, his native state, where he was born in 1890. During the 58 years that intervened, his activities took him to many parts of the United States, and to other countries of the world. For his formal education he went to the Pennsylvania State College, from which, in 1912, he was graduated with a B.S. degree. The next fourteen years he spent with several Utah and Montana mining companies, in managerial positions; in the same period he also did some consulting work. He then left for the Belgian Congo, to direct the research department of the Union Miniere du Haut Kantanga. In the forties he returned to the States.

ADAM ALEXANDER BOYD (Member 1909), managing director of Mount

Morgan Ltd., died at Brisbane, Australia, on Dec. 16. Mr. Boyd had been affiliated with this mining company ever since its incorporation in 1929; and before that time, he was general manager of its predecessor, Mount Morgan Gold Mining Co. Although he spent the greater part of his life in Australia, he was originally from Scotland. Mr. Boyd did his apprentice mining in the collieries of that country until 1889, when, at the age of 23, he migrated to Australia. There, he continued his work, but in supervisory capacities. After brief associations with a few mining outfits, he joined Mount Morgan.

CHESTER H. GIBBONS (Member 1937), manager of the testing equipment department at the Baldwin Locomotive Works, passed away April 14, 1948, while in his sixtieth year. At the time of his death, Mr. Gibbons was considered an authority on test machines—a reputation that was built up through a self-made career. His first position was that of a draftsman, with the Marion Steam Shovel Co. in Ohio, his native state; and although he alternated his jobs between Marion and other machinery manufacturers he spent a considerable amount of time with the Company. However, in 1930, he severed that connection completely when he joined the Baldwin-Southwark Corp. in Philadelphia, as technical advisor in the testing machine division. From there he went to the Baldwin Locomotive Works. That he was devoted to his field is evidenced by his record as the author of "A History of Testing Machines," as well as numerous papers which were presented before the AIME, ASME, and ASTM.

CHARLES ELLIS MENGEL (Member 1944), vice-president of the Locust Coal Co. and director of Weston Dodson & Co., died on Dec. 17 at St. Luke's Hospital in Bethlehem, Pa. Mr. Mengel's sixty-year career was almost completely devoted to the Pennsylvania coal industry, save for some statistical work with the Panama Canal Commission, during the Canal's construction. (This exception in his career stemmed from his training at the Bethlehem Business College.) He was introduced to the industry in 1915, when he joined Weston Dodson, and by 1941 he was assistant to the president of that concern as well as a director of the Locust Coal Co. He also was connected with the Locust Mountain Coal Co. and the Pine Hill Coal Co. As a strong advocate of first aid work, he was largely responsible for the health and safety advances made at the various companies with which he was associated. In the same vein, Mr. Mengel was an active member of the American Red Cross, having served the Bethlehem chapter of that organization in a number of executive capacities since 1931. He also directed much of his energy toward his local chapter of the Boy Scouts of America.

ROBERT ANSEL PIERCE (Member 1942), director of exploration for the Potash Co. of America, died in Denver on Dec. 26, at the age of 68. He had been with the Company since 1931, when he was employed as the chief engineer. From this position he rose to those of assistant general manager and director of exploration. The remaining thirty years of Mr. Pierce's professional career were spent on brief engagements with numerous other mining concerns. The training for his profession was obtained at the Colorado State College, from which he was graduated in 1900 with the degree of B.S.

DAVID GARRETT KERR (Member 1886), member of the Institute's Legion of Honor and retired vice-president of U. S. Steel Corp., died Oct. 18 in Pittsburgh, at the age of 84. Before associating with U. S. Steel, Mr. Kerr worked for many years as a chemist in Wilkinsburg, Allegheny County, Pa.

Philip Read Bradley

PHILIP READ BRADLEY (Member 1902), West Coast mining executive, died on Dec. 31 at 73 years of age. At the time of his death, Mr. Bradley was chairman of the board of the Alaska Juneau Gold Mining Co., with whom he had been associated for over thirty years. He started that association as general superintendent of the Company's mines in Juneau after first acquiring some experience in other Alaskan mines. Otherwise, Mr. Bradley spent most of his lifetime in his home state, California. Upon his graduation from the University of California in 1896, he worked for a while at the Spanish mine of the Washington Nevada Co. before setting up an office in the Crocker Building, in San Francisco. It was from those headquarters that he conducted his early consulting practice, and directed his later executive activities.

GORDON T. WILLIAMS (Member 1944), materials engineer for Pratt & Whitney Aircraft, passed away Sept. 19 last, after a long illness. He was 46 years old. Mr. Williams saw the beginnings of his metallurgical career in Cleveland, where he was born, raised, and educated. His first position was with Thompson Products, Inc., of that city. After working with the firm for four years he continued his following at the Cleveland Tractor Co. and at Deere & Co. Then, towards the end of 1943 he joined Pratt & Whitney. Although Mr. Williams has written many technical papers on metallurgical subjects, he is probably best known for his book, "What Steel Shall I Use."

FRANK MERTON WARREN (Member 1910), vice-president and secretary of Langdon-Warren Mines, Inc., in Minneapolis, Minn., died Oct. 16, shortly before his 73rd birthday. Mr. Warren was a native of Minneapolis and had attended the University of Minnesota there. After he was graduated with an E.M. degree in 1899, he remained in the same area, doing geological field work on the Vermillion range for George Warren. He continued his association with Mr. Warren in this way, examining mines and making mining investments, for many years. Then, in 1938, the two men formally incorporated their business, and founded Langdon-Warren Mines, Inc.

HOWARD PATTERSON ZELLER (Member 1908), vice-president of Jamison Coal and Coke Co., and former vice-president of the old Donner Union Coke Corp., died at his home in Greensburg, Pa., on Dec. 10, at the age of 64. Mr. Zeller was a familiar figure in the coal and coke field, through his association with it for almost half a century—since 1905. At that time, right after his graduation from Ohio State University with a degree in mining engineering, he initiated his career with jobs in mining companies of Mexico. From there he went to the Birmingham, Ala., mining district; and then to Pennsylvania, to become superintendent of Republic Steel Corp.'s mines and beehive coke ovens. He left this work in 1912, when Republic installed its first battery of chemical recovery type coke ovens, to become assistant superintendent at the new plant in Ohio. His next job was during World War I, as head of the toluol division of the ordnance department. After the war, Mr. Zeller moved to Buffalo where he joined the Donner Union Coke Corp. He resigned in 1930 to take on the position he was holding at the time of his death.

### Necrology

| *Date Elected* | *Name* | *Date of Death* |
|---|---|---|
| 1906 | Charles E. Le Neve Arnold | Jan. 23, 1949 |
| 1909 | Adam Alexander Boyd | Dec. 16, 1948 |
| 1902 | Philip Read Bradley | Dec. 31, 1948 |
| 1905 | Edward E. Bugbee | Feb. 2, 1949 |
| 1923 | Cash I. Cook | Dec. 22, 1948 |
| 1917 | L. H. Duschak | Nov. 27, 1948 |
| 1915 | C. D. Grier | Dec. 2, 1948 |
| 1914 | Elwin B. Hall | Jan. 20, 1949 |
| 1904 | Charles E. Locke | Sept. 24, 1948 |
| 1943 | Norman Mackenzie | Dec. 8, 1948 |
| 1936 | F. A. G. Maxwell | Dec. 26, 1948 |
| 1944 | Charles E. Mengel | Dec. 17. 1948 |
| 1942 | Robert A. Pierce | Dec. 26, 1948 |
| 1884 | Theodore W. Robinson | Dec. 30, 1948 |
| 1894 | Frederick Roeser | Dec. 21, 1948 |
| 1917 | A. D. Shankland | Jan. 5, 1949 |

# Proposed for Membership

Total AIME membership on January 31, 1949, was 15,280; in addition 3696 Student Associates were enrolled.

### Admissions Committee

Albert J. Phillips, Chairman; James L. Head, Vice-Chairman; George B. Corless, T. B. Counselman, George C. Heikes, W. B. Plank, P. D. Wilson, E. M. Wise.

*Institute members are urged to review this list as soon as the issue is received and immediately to wire the Secretary's office, night message collect, if objection is offered to the admission of any applicant. Details of the objection should follow by air mail. The Institute desires to extend its privileges to every person to whom it can be of service but does not desire to admit persons unless they are qualified.*

*In the following list C/S means change of status: R, reinstatement; M, Member; J, Junior Member; A, Associate; S, Student Associate; F, Junior Foreign Affiliate.*

### ARIZONA

*Claypool*—FLORI, WILLIAM JOSEPH. (C/S—S-J). Junior engineer, Miami Copper Co.

*Douglas* — McCARTHY, DONALD PAUL. (C/S—S-J). Test engineer, Phelps Dodge Corp. ROGERS, GEORGE REINER. (J). Geophysical engineer, Phelps Dodge Corp.

*Inspiration*—GOULD, ALLISON JAY. (M). General foreman, leaching plant, Inspiration Cons. Copper Co.

*Prescott*—GIBBS, FRED. (R—M). Mine operator for self.

*Superior* — CALDWELL, EDWARD JEROME. (C/S—J-M). Smelter superintendent, Magma Copper Co.

*Tempe*—MURDOCK, JOHN BENJAMIN. (A.) President, Perlite Corp.

*Tucson* — BENDER, FREDRICK NOAH. (C/S—S-J). Metallurgist, Bureau of Mines.

### CALIFORNIA

*Altadena*—SCOTT, DAVID BURNET. (R—M). Sales manager, American Potash and Chemical Corp.

*Burlingame* — BRYANT, FLOYD SHERMAN. (A). Director and vice-president, Standard Oil Co. of California.

*Glendale*—PURMORT, LOUIS EDWARD. (J). Sales engineer, Nicholas A. D'Arcy Co.

*La Habra*—CURLETTE, JAMES ARTHUR. (J). Production engineer, Standard Oil Co. of California. RIORDAN, MATHEW BARRET. (M). Chief metallurgist, Byron Jackson Co.

*Long Beach*—FORSYTHE, RUSSELL LOWELL. (M). District manager, Schlumberger Well Surveying Corp. LEFTWICH, JOHN BALL. (R,C/S—S-J). Associate engineer, Eastman Oil Well Survey Co. PENNEY, CHESTER OSGOOD, JR. (J). Engineer, Southwest Exploration Co.

*Los Angeles*—GAYMARD, ROBERT GEORGES. (J). Petroleum engineer, Societe Nationale de Recherche et d'Exploitation des Petroles en Algiers. KOPFF, MICHEL JEAN. (J). Petroleum engineer, Syndicat d'Etudes et Recherches Petrolierg. SAWYER, JOSEPH ADDISON. (M). Oil lease consultant.

*Pacific Palisades*—SAMMONS, FREDERICK C. (A). Western manager, General Refractories Co.

*San Mateo*—EARDLEY, WENDELL ARTHUR. (M). Chief petroleum engineer, Standard Oil Co. of California.

*South Pasadena*—THACHER, JOHN H., JR. (M). Manager, producing department, Southern district, Standard Oil Co. of California.

*Taft*—CRAMER, THOMAS DUDLEY. (C/S—S-J). Junior petroleum engineer, Standard Oil Co. of California.

*Whittier* — CRAGGS, DONALD EDGAR. (C/S—S-A). Associate production engineer, Union Oil Co. GUTSCHOW, NATHAN ROBERT. (M). Laboratory engineer, General Petroleum Corp. JAMES, FLOYD DIXIE. (R,C/S—J-M). Head, process engineering department, Wigton-Abbott Corp. SMILEY, JAMES WALTER. (J). Drilling fluid engineer, General Petroleum Corp.

### COLORADO

*Denver*—BUCHER, FREDERICK J. (C/S—J-M). Natural gas engineer, Federal Power Comm. COX, JAMES GILBERT. (R,C/S—S-M). Assistant superintendent, Globe plant, American Smelting and Refining Co. McCAVITT, FRANCIS JOHN. (C/S—S-A). Chief of party, U. S. Geological Survey.

*Leadville* — ENOCHS, RICHARD CLINTON. (C/S—S-J). Junior metallurgist, American Smelting and Refining Co.

*Silverton*—BREYMANN, JOHN BERNARD, III. (C/S—S-J). Metallurgist, Shenandoah-Dives Mining Co.

### CONNECTICUT

*Westport*—HOCHSCHEID, ROBERT EUGENE. (C/S—S-J). Junior engineer, The Dorr Co. WALL, CLARENCE JOSEPH. (R,C/S—S-J). Research engineer, The Dorr Co.

### DISTRICT OF COLUMBIA

*Washington*—TRIPP, PERRY C. (M). Metallurgical engineer and manufacturer's representative.

### FLORIDA

*Lakeland* — HOLLINGSWORTH, CLINTON ALLEN. (M). Research supervisor, Coronet Phosphate Co.

*Pierce*—QUINA, HERBERT RULL. (M). Project engineer, American Agricultural Chemical Co.

### IDAHO

*Kellogg* — REDDING, CURTIS FRANKLIN. (M). Mine superintendent, Spokane-Idaho Mining Co. ROSCOE, JOHN G. (C/S—S-J). Junior engineer, Bunker Hill & Sullivan Mining and Concentrating Co.

*Wallace*—KIMES, DALE KENNETH. (C/S—S-A). Federal Mining and Smelting Co. SQUIRES, ROBERT LAWRENCE. (C/S—S-J). Sampler, Day Mines, Inc.

### ILLINOIS

*Aurora*—DE WALD, LEE HENRY. (R—M). Development engineer, National Cylinder Gas Co.

*Carmi*—HARMON, BILL GILBERT. (J). Petroleum engineer, Superior Oil Co.

*Chicago* — HOBY, THEOPHILUS JOSEPH. (R,C/S—S-M). Technical operating trainee, Republic Steel Corp. JORDAN, CHARLES WILLIAMS, JR. (C/S—S-J). Control metallurgist, Wisconsin Steel Works. McCOLLUM, HERBERT CLAYTON. (M). Vice-president, Allen & Garcia Co. MORRISON, JOHN ELMER. (M). Engineer, mining division, Link-Belt Co. STEUDEL, ROBERT WARREN. (M). Supervisor, finishing end merchant mills, Wisconsin Steel Works.

*East St. Louis*—LANE, CHARLES FREDERICK. (M). Assistant to general superintendent, American Zinc Co. of Illinois.

*Urbana* — GRAF, DONALD LEE. (C/S—S-J). Associate geologist, Illinois Geological Survey.

### KANSAS

*Ellinwood* — BORGESON, WALLACE ALFRED, JR. (M). Petroleum engineer, Stanolind Oil and Gas Co. NATION, WILLIAM ROY. (J). Junior petroleum engineer, Stanolind Oil and Gas Co. OAKLEY, JAMES BERRY, JR. (J). Petroleum engineer, Stanolind Oil and Gas Co.

*Eureka*—KLUCK, FRED V. (R,C/S—S-M). District engineer, Ohio Oil Co. WHITTAKER, CLIVE CHARLES. (M). Petroleum engineer, C. C. Whittaker.

*Great Bend* — ROBERTSON, HERBERT R. (M). Development engineer, Dowell Incorporated.

*Raymond* — ROCKHOLD, JAMES WALTER. (C/S—S-J). Petroleum engineer trainee, The Texas Co.

*Russell*—NYGAARD, CLAYTON W. (M). Assistant district superintendent, Sohio Petroleum Co.

*Wichita*—BERG, J. ROBERT. (M). Associate professor of geology, University of Wichita. CUMMIN, JAMES ALEXANDER. (M). District manager, Dowell Incorporated. HALL, BROOKS. (R,C/S—S-J). Geological scout Stanolind Oil and Gas.

### KENTUCKY

*Jenkins*—STOREY, RICHARD WATSON. (J). Assistant chief engineer, Consolidation Coal Co.

*Lexington* — THOMPSON, LAWRENCE SIDNEY. (A). Director of libraries, University of Kentucky.

*Louisville*—HAND, THOMAS. (M). Acting head, research department, Corhart Refractories Co.

*Pikeville*—HEDLAND, R. A. (M). General manager, Utilities Elkhorn Coal Co.

### LOUISIANA

*Lafayette*—CORNELL, DREW. (C/S—J-M). Partner, Bates & Cornell.

*Monroe*—SMITH, DUNCAN McLAURIN, JR. (C/S—S-J). Petroleum engineer, The California Co.

*New Orleans* — WILLIAMS, DONNAUD BENTLEY. (R,C/S—S-J). Production engineer, The Texas Co.

*Shreveport*—LOEB, HERMAN. (J). Geological scout, Union Producing Co. YOUNG, VERNON ROARE, JR. (M). Division engineer, Halliburton Oil Well Cementing Co.

### MARYLAND

*Baltimore*—RAILING, LEWIS IRA, JR. (C/S—S-J). Project engineer, Ford, Bacon & Davis, Inc.

### MICHIGAN

*Alabaster* — APPLEYARD, FRANK

CHARLES. (R,C/S—J-M). Quarry superintendent, U. S. Gypsum Co.

### MINNESOTA

*Coleraine* — RUBOW, IRVIN H. (R,C/S—S-M). Mine superintendent, Oliver Iron Mining Co.

*Duluth*—MOBERG, NORMAN ALBERT. (C/S—J-M). Mining engineer, Oliver Iron Mining Co.

*Eveleth*—BURGETT, PAUL V. (M). Chief engineer, Eastern district, Oliver Iron Mining Co.

### MISSOURI

*Joplin*—ELLIS, EDGAR Y. (R—M). Supervising engineer, Reconstruction Finance Corp.

*Rolla* — McELVENNY, LINDEN THOMAS. (M). Mining engineer, Bureau of Mines.

*St. Louis*—FRANK, ALBERT JOSEPH. (M). Instructor in geology, St. Louis University.

### NEVADA

*Gabbs* — WINES, STANLEY VERNON. (C/S—S-M). Chief metallurgist, Standard Slag Co.

*Reno*—LUCE, HAROLD HUME. (A). Partner and secretary-treasurer, Riley Mine and Northern Nevada Mining Co.

*Virginia City*—KENDALL, ROBERT ELI. (C/S—S-J). Assistant mining engineer, Dayton Consolidated Mines Co.

### NEW JERSEY

*Delanco* — JACKSON, FREDERICK ROBERT. (C/S—J-M). Metallurgist, Riverside Metal Co.

*Mahwah* — WEYMER, HORACE JEROME. (C/S—S-J). Assistant metallurgist, American Brake Shoe Co.

*Metuchen*—STODDARD, CARL KERBY. (M). Development engineer, titanium division, National Lead Co.

*Plainfield*—KATRAUSKY, JOSEPH. (A). Assistant treasurer, Guaranty Trust Co. of N. Y.

### NEW MEXICO

*Deming*—WALLACE, ROBERT EDWARD. (C/S—S-J). Engineer, general chemical division, Allied Chemical and Dye Corp.

*Silver City* — BYNUM, CHARLES GERALD. (M). Assistant city engineer, Silver City, N. Mex.

### NEW YORK

*Baldwin*—MADSEN, STANLEY WALTER. (C/S—S-J). Trainee, Phelps Dodge Copper Products Corp.

*Brooklyn*—LEVINE, NATHAN M. (A). Assistant in mineral engineering, Columbia University.

*New York*—CAMPBELL, GEORGE. (M). Chief metallurgist and chemist, Plessey Co.

*Suffern* — TAYLOR, RICHARD D. (M). Plant manager, federated metals division, American Smelting and Refining Co.

*White Plains*—COHAN, ALVIN SEYMOUR. (J). Research metallurgist, American Electro Metal Corp.

### OHIO

*Canton*—TURNER, JOE S. (C/S—S-J). Research metallurgist, Timken Roller Bearing Co.

*Cincinnati* — HAUCK, FREDERICK ALEXANDER. (M). President, Continental Mineral Processing Corp.

*Columbus* — LANGSTON, BENNY. (C/S—S-J). Research engineer, Battelle Memorial Institute.

*Lakewood*—HENIKA, MORGAN, JR. (C/S—S-J). Development engineer, National Carbon Co.

*Middletown* — RAUTIO, LAURIE JOHN. (C/S—J-M). Manager, Clayton & Lambert Mfg. Co.

### OKLAHOMA

*Broken Arrow*—BALTOSSER, ROBERT WILLCOX. (C/S—J-M). Research engineer, Seismograph Service Corp.

*Duncan* — HALLIBURTON, JOHN CARROLL. (A). President, Halliburton Oil Well Cementing Co.

*Ponca City*—MILLIKIN, BRYANT TAGGART, JR. (R,C/S—S-M). Petroleum reservoir engineer, Continental Oil Co.

*Tulsa*—FELL, MORRIS BORTEL. (A). Partner, Fell & Wolfe Oil Co., and Bradford Pipe Cement Lining Co. GLOVER, ROBERT CHESLEY. (A). District manager, Baker Oil Tools, Inc. LUBINSKI, ARTHUR. (M). Petroleum engineer, Barnsdall Research Corp. SCHULTZ, PAUL ROBERT. (M). Manager, economics department, Stanolind Oil and Gas Co.

### PENNSYLVANIA

*Bellefonte*—KACHIK, DAVID JOSEPH. (R,C/S—S-J). Instructor in mining engineering, Pennsylvania State College.

*Bradford*—BAUER, GEORGE GERALD. (A). Editor, *Producers Monthly,* Pennsylvania Oil Producers Assn.

*Cresson*—FOREMAN, JOHN WICKS. (C/S—S-J). Junior mining engineer, Monroe Coal Mining Co.

*Easton*—WILSON, JAMES C. (J). Instructor of metallurgy, Lafayette College.

*Hazleton*—BUTLER, CHARLES TOLHURST. (M). Assistant general manager, Central Pennsylvania Quarry Stripping and Construction Co. GLANCE, ARTHUR STUART. (R,C/S—J-M). Safety engineer, Coal Operators Casualty Co.

*McKeesport* — WILLSON, ROBERT THOMAS. (J). Editor, Steel Publications, Inc.

*McKees Rocks*—POLLACK, JOHN FRANCIS. (C/S—J-M). Special assistant superintendent, open hearth and Bessemer, Jones & Laughlin Steel Corp.

*Olyphant* — BOURGER, EUGENE JOHN. (A). Assistant chief inspector, Hudson Coal Co.

*Philadelphia* — GREENBERG, WILLIAM BAER. (J). Design engineer, Elmer H. Greenberg. JORDAN, THOMAS GIHON. (M). President, Maryland New River Coal Co.

*Pittsburgh*—CASHDOLLAR, L. W. (M). Chief metallurgist, Union Electric Steel Corp. GEORGE, EMERSON LOGAN. (C/S—S-J). Junior engineer, McConway-Torley, Inc.

*Reading* — STICKLER, CHARLES WESLEY, JR. (R,C/S—J-M). Associate professor of mining, Pennsylvania State College.

*State College*—ASMAN, ARNOLD WILLIAM. (R,C/S—J-M). Chief of mining division, Pennsylvania State College.

*Tamaqua*—MYERS, FRED WOODWELL. (M). Special engineer, Lehigh Navigation Coal Co.

*Wilkes-Barre* — REINHARDT, ROBERT CHARLES. (M). Chief draftsman, Bureau of Mines.

### TENNESSEE

*Norris*—HAMBY, DURWARD E. (J). Associate metallurgist, Oak Ridge National Laboratory.

### TEXAS

*Alice*—HARPER, LLOYD G. (C/S—S-A). Petroleum engineer, The Texas Co. TAYLOR, MARSHALL WILMER, II. (R,C/S—S-M). Production superintendent, Kirkwood & Morgan, Inc.

*Corpus Christi*—BEATTY, RICHARD WILLIAM. (M). Division gasoline plant superintendent, Humble Oil and Refining Co. CREIGH, JOHN LOCK. (J). Junior petroleum engineer, Humble Oil and Refining Co. FULLINWIDER, THEODORE ROLLA. (M). Sales engineer, Mission Mfg. Co. McKENZIE, BILL. (A). General manager, Mack Well Service Co. VAUGHAN, HENRY DANIEL. (M). District sales engineer, Lane-Wells Co.

*Dallas*—BARBOUR, JOHN WALDWYN, JR. (M). District engineer, Core Laboratories, Inc. BRAINARD, GUY REED, JR. (M). Assistant division superintendent, Seaboard Oil Co. of Delaware. KIESCHNICK, WILLIAM FREDERICK, JR. (J). Administrative assistant to director of production research, Atlantic Refining Co. NOBLES, MELVIN ALFRED. (M). Senior research engineer, Magnolia Petroleum Co.

*El Campo*—PAYTON, JOY TRUMAN. (R,C/S—S-M). District reservoir engineer, The Texas Co.

*Fort Worth* — NUSS, WILLIAM FRANK, JR. (J). Petroleum engineer, Stanolind Oil and Gas Co.

*Galveston* — O'BRYAN, OLIVER D. (C/S—S-J). Junior engineer, Stanolind Oil and Gas Co.

*Graham*—PARRISH, FRANK, JR. (J). Junior engineer, Schlumberger Well Surveying Corp.

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*Midland* — GROSSMAN, WALDO LAWRENCE. (M). Division engineer, Halliburton Oil Well Cementing Co.

*Premont*—ANGELI, ORLANDO. (J). Field engineer, The Texas Co.

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*Wichita Falls*—MAUCINI, JOSEPH JOHN. (M). District superintendent, land and geological departments, Superior Oil Co.

### UTAH

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*Park City* — GILBERT, RAY E.

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WEST VIRGINIA

*Charleston*—MINER, GORDON MORRIS. (C/S—S-J). Sales engineer, Goodman Mfg. Co.

WISCONSIN

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WYOMING

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BRITISH COLUMBIA

*Victoria*—SARGENT, T. E. HARTLEY. (R,C/S—S-M). Chief mining engineer, B. C. Department of Mines.

VERA CRUZ

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ARGENTINA

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FRANCE

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UNION OF SOUTH AFRICA

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CYPRUS

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NEW SOUTH WALES

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SOUTH AUSTRALIA

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## Student Associates

### Elected January 19, 1949

| | |
|---|---|
| Rex Golson, Jr. | Univ. Ala. |

### Elected February 16, 1949

| | |
|---|---|
| James L. Adkins | La. State Univ. |
| Oscar Albritton | Texas Mines & Met. |
| Otis B. Allred | Texas Tech. Coll. |
| Leslie U. Anderson | Penn. State |
| William Arbiter | MIT |
| Gerald O. Bailey | Texas Tech. Coll. |
| James T. Baker | Univ. Minn. |
| Arthur W. Ball, Jr. | Texas Tech. Coll. |
| James L. Banfield, Jr. | Penn. State |
| Addison S. Barker | Texas Tech. Coll. |
| George A. Basta, Jr. | MIT |
| Norman Bellinger | La. State Univ. |
| Lewis W. Berger | MIT |
| Richard J. Bowman | Texas A&M |
| Robert K. Bradley | Texas Tech. Coll. |
| Dale C. Brittain | Univ. Ariz. |
| Glen D. Brooks | Texas Tech. Coll. |
| Herbert F. Buchholtz | Univ. Kans. |
| Wesley H. Buice | Texas Tech. Coll. |
| George W. Burgess | Colo. Sch. Mines |
| Derrell D. Burrell | Texas Tech. Coll. |
| Henry M. Butler | MIT |
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| Horace B. Bynum | Texas Tech. Coll. |
| Walter L. Cheshire | Texas Tech. Coll. |
| William J. Childress, Jr. | La. State Univ. |
| Earl J. Chisholm | Texas Tech. Coll. |
| Joseph R. Christian | La. State Univ. |
| Paul R. Clevenger | Texas A&M |
| Dean E. Click | Texas Tech. Coll. |
| Carl R. Coleman | Texas Tech. Coll. |
| Jess B. Coleman, Jr. | Texas Tech. Coll. |
| Lester D. Collier | Texas A&M |
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| Wallace Cooper | Texas Tech. Coll. |
| John E. Coppinger | Texas Tech. Coll. |
| Roy E. Corliss | Univ. Wash. |
| Mitchell B. Corriher, Jr. | N. C. State |
| Foy E. Cox | Texas Tech. Coll. |
| Frederick G. Cox, Jr. | La. State Univ. |
| J. B. Cox | Texas Tech. Coll. |
| William B. Cox | Texas Tech. Coll. |
| Donald G. Dahle | Univ. Idaho |
| William E. Dalton | La. State Univ. |
| Victor V. Damiano | Univ. Penn. |
| Jack M. Darden | Texas Tech. Coll. |
| Camille P. Den Dooven | Mich. Min. & Tech. |
| Billy B. Denny | Texas Tech. Coll. |
| Thomas H. Dial | Texas Tech. Coll. |
| Emory E. Diltz | Texas Tech. Coll. |
| Lloyd C. Doud | Texas Tech. Coll. |
| Cleo C. Dunlap | Texas Tech. Coll. |
| Marsden J. Dupuy | La. State Univ. |
| Quentin Dyce | S. Dak. Sch. Mines |
| Samuel P. Eatherly | Texas Tech. Coll. |
| Rodney P. Eggleston | Texas Tech. Coll. |
| Harvey B. Elder, Jr. | Texas A&M |
| William T. Elkin | Texas Tech. Coll. |
| Joy Elledge | Texas Tech. Coll. |
| Earl G. Ellis | Texas Tech. Coll. |
| Glenn E. Emmett | Texas Tech. Coll. |
| Joseph R. Enloe, Jr. | Texas Tech. Coll. |
| Truett Enloe | Texas Tech. Coll. |
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| Jose H. R. Falcao | MIT |
| Ray J. Foster | Texas Tech. Coll. |
| James C. Fulton | Univ. Penn. |
| Edward R. Funk | MIT |
| Thad E. Furlong | Lewis & Clark Coll. |
| Ralph A. Gaddie | Texas Tech. Coll. |
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| William P. Garrett | Texas Tech. Coll. |
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| Elbert E. Gilder | Texas Tech. Coll. |
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| Henry M. Girner | La. State Univ. |
| James B. Girod | Penn. State |
| George B. Griswold | N. Mex. Sch. Mines |
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| Curtis Hancock | Texas Tech. Coll. |
| Charles S. Hardwick | Texas Tech. Coll. |
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| Tom P. Hart | Texas Tech. Coll. |
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| Donald L. Henderson | Texas Tech. Coll. |
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| Louis L. Hunt | Texas Tech. Coll. |
| Richard P. Hurlebaus | Univ. Penn. |
| Thomas E. Huzzey | W. Va. Univ. |
| William C. Ireland | Penn. State |
| Guy D. Irvin, Jr. | Texas Tech. Coll. |
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| Barley G. Iverson | Texas Tech. Coll. |
| John H. Jett | Univ. Ariz. |
| Robert E. Johnston, Jr. | Texas Tech. Coll. |
| Billy R. Jones | Texas Tech. Coll. |
| H. A. Jones | Texas Tech. Coll. |
| Ralph E. Jones, Jr. | S. Dak. Sch. Mines |
| Alvin Kaufman | Penn. State |
| Harold L. Kendrick | Texas Tech. Coll. |
| Ward W. Killingsworth, Jr. | Texas Tech. Coll. |
| John V. Kincaid | Texas Tech. Coll. |
| Edwin B. King | Univ. Ariz. |
| Norman S. King | Texas Tech. Coll. |
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| Eugene Kozik | Univ. Pittsburgh |
| Manuel Kraus | Penn. State |
| Joseph L. Krieg | Texas Tech. Coll. |
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| Kenneth C. Lamb | Okla. A&M |
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| Don L. Libbey | Texas Mines & Met. |
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| Joseph M. Lynch, Jr. | MIT |
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| William P. McBee | Texas Tech. Coll. |
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| James R. McMurry | Texas Tech. Coll. |
| Richard G. McRae | La. State Univ. |
| Donald G. McWilliams | Texas Tech. Coll. |
| Paul Meadows | Texas Tech. Coll. |
| Morgan Mickleberry | La. State Univ. |
| Jim W. Mims | Texas A&M |
| William N. Moseley | Texas A&M |
| Brian E. Myers | Texas Tech. Coll. |
| John A. Nelson | Univ. Kans. |
| Harold J. Norris | Texas Tech. Coll. |
| Gordon L. Nunn | Texas A&M |
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| J. C. Owen | Texas Tech. Coll. |
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| John B. Peck | Univ. Minn. |
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| Allen T. Robinson | Univ. Calif. |
| David A. Robinson | Stanford Univ. |
| Elton E. Rodgers, Jr. | Texas Tech. Coll. |
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| Leo J. Schaefer | Texas Tech. Coll. |
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| Joe L. Terry | Texas Tech. Coll. |
| Fred M. Thompson | Texas Tech. Coll. |
| Richard E. Thompson | Univ. Minn. |
| Roy H. Trice | Texas Tech. Coll. |
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| Miller R. Van Eaton | Texas Tech. Coll. |
| Sam T. Vinturella | La. State Univ. |
| Donald F. Virant | Univ. Minn. |
| William R. Waag | Penn State |
| Jack L. Waldrep | Texas Tech. Coll. |
| Patrick N. Walseth | Univ. Minn. |
| Max H. Walthall | Texas Tech. Coll. |
| Teh Po Wang | Univ. Penn. |
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| Paul M. White | Texas A&M |
| Walter L. Williams | Texas A&M |
| Kenneth A. Wood | Texas Tech. Coll. |
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# The Recovery of Cadmium from Cadmium-copper Precipitate, Electrolytic Zinc Co. of Australasia, Risdon, Tasmania

G. H. ANDERSON*

CADMIUM-COPPER precipitate, a by-product of the purification stage of the zinc plant, is composed mainly of zinc, cadmium and copper in varying amounts depending on the efficiency of precipitation and the cadmium and copper contents of the impure solution treated.

The composition range is approximately: cadmium 10–12 pct, copper 6–8 pct, and zinc 30–35 pct. As received at the cadmium plant, the precipitate is a dark gray to black press cake produced by filter pressing the flocculent cadmium-copper precipitate formed when impure zinc solution is agitated with zinc dust.

The details of the cadmium-copper precipitation are to be found in the paper "Electrolytic Zinc at Risdon, Tasmania," by W. C. Snow. *Transactions* AIME, **121,** 501.

The treatment, in addition to recovering cadmium as metal, yields a copper product as a residue for realization and recovers in solution for return to the zinc plant, the excess of zinc dust used during purification.

The recovery of cadmium metal is approximately 200 tons† per year, but, with the amount of copper residue recovered, varies with the zinc production tonnage, composition of the original concentrates, degree of roasting and other operational factors.

The operations involved in the recovery of the foregoing materials are carried out in a building adjacent to the purification section of the zinc plant and can best be described by dividing the process into the following stages:

1. Oxidation and Grinding of the cadmium-copper precipitate.
2. Leaching and Filtering.
3. Precipitation of cadmium.
4. Oxidation and Grinding of the precipitated cadmium.
5. Leaching oxidized cadmium precipitate and Purification of leach solution.
6. Electrolysis.
7. Melting, Casting and Packing.

A feature of the process is the use of two distinct solution circuits. Spent electrolyte from the zinc plant circuit containing about 10 pct sulphuric acid is used as the primary solvent of the cadmium and zinc present in the oxidized precipitate. When the cadmium is later separated by precipitation and filtering, the filtrate, originally zinc plant spent electrolyte and now fortified in zinc, is returned to the zinc plant.

San Francisco Meeting, February 1949.

TP 2525 D. Discussion of this paper (2 copies) may be sent to *Transactions* AIME before June 15, 1949. Manuscript received October 1, 1948.

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The precipitated cadmium, after oxidation, is redissolved in spent electrolyte from cadmium electrolysis which solution is in closed circuit within the cadmium plant except for discards to the zinc plant circuit as mentioned in Section 5 hereinafter. (Fig 1.)

Details of the various operations follow.

## 1. Oxidation and Grinding of the Cadmium-copper Precipitate

The precipitate having had a preliminary drying by compressed air in Dehne filter presses in the zinc plant is trucked to a storage platform of sufficient length to store 3 to 4 days' production separately.

After 48 hr exposure to atmosphere, oxidation is sufficient to enable all cadmium and zinc but only a portion of the copper to be dissolved in dilute sulphuric acid.

The oxidized precipitate is shovelled into trucks and, after weighing and sampling, is broken in size by means of

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† Throughout this paper the long ton of 2240 lb and the Imperial gallon are used.

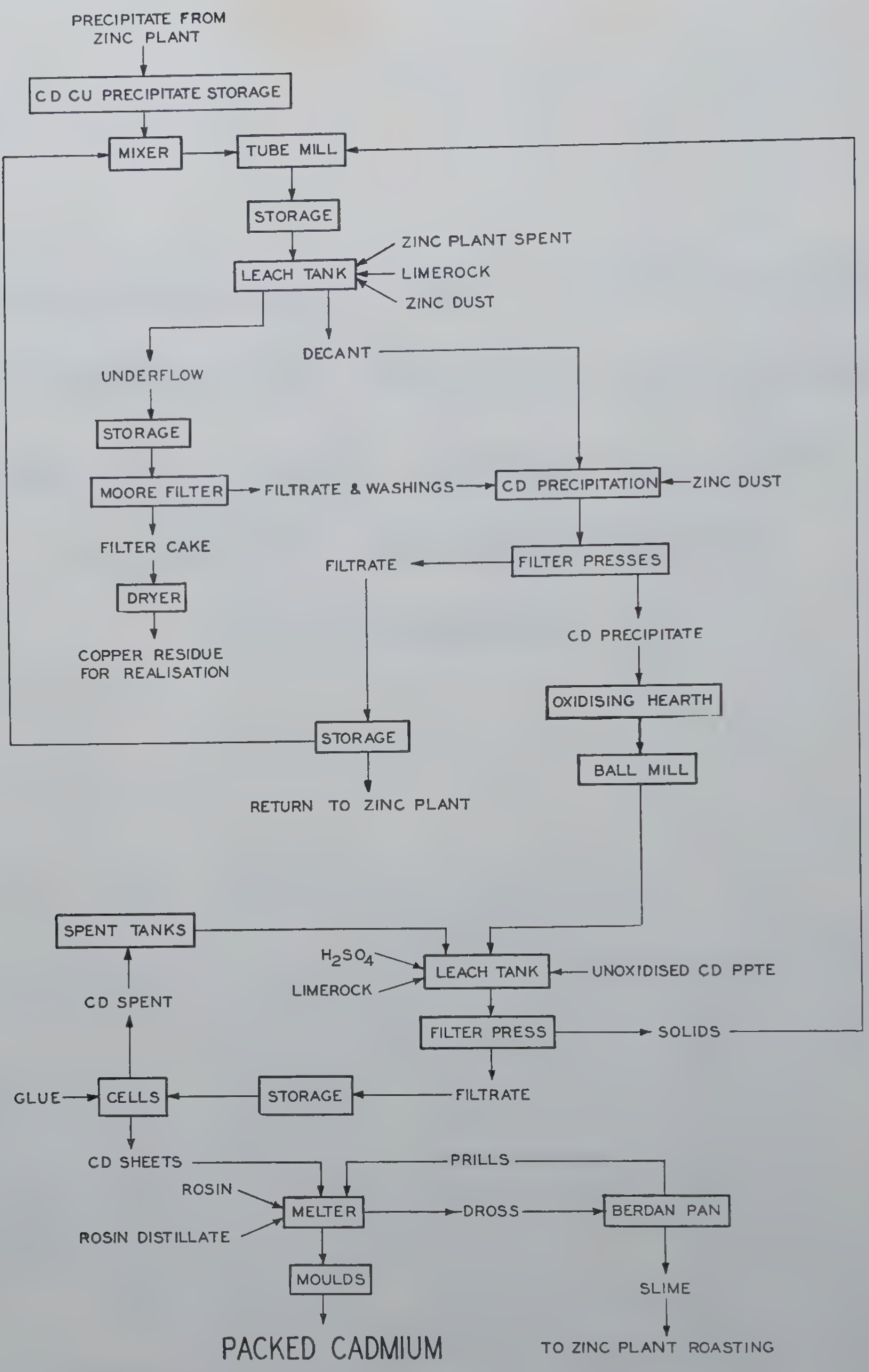

FIG 1—Flowsheet.

right and left handed blades rotating in a shallow mild steel trough.

Return solution (see Stage 3) is added to form a pulp which passes to a tube mill 5 ft long and 3 ft diam having cast steel liners and loaded with flint pebbles.

The use of return solution is restricted to produce a thick pulp which is elevated to a wooden storage tank of 3200 gal capacity and provided with air agitation.

## 2. Leaching and Filtering

Leaching is carried out in a wooden tank of approximately 14,000 gal capacity, having a conical bottom and provided with both mechanical and air agitation.

Discharge is through a plug cock but, in addition, the tank has a side discharge to which is fitted, inside the tank, an armored rubber hose for decanting clear solution after settlement of the solids.

The tank is covered and ventilated to atmosphere. Approximately 7000–8000 gal of zinc plant spent electrolyte containing 90–95 g sulphuric acid and 45–50 g zinc per liter are run into the leaching tank and after agitation is started the ground cadmium-copper precipitate is charged until the acidity of the solution falls to 5–6 g sulphuric acid per liter. Agitation is continued for another 5–6 hr by which time the acidity is reduced to 1–2 g sulphuric acid per liter, then ground limestone is added slowly until a pH 3–4 is reached.

Approximately 30 min. later a sample is taken, tested for copper and the calculated quantity of zinc dust required to remove copper in excess of 0.5 g per liter, is added. (See Appendix 1.)

The zinc dust containing 45–50 pct of minus 250 mesh material, used in this and other stages of the recovery of cadmium, is produced at Risdon by atomizing molten high grade zinc with compressed air at 200 psi pressure.

Control of the copper content of the solution is important, and is considered to have three distinct advantages.

First, its subsequent precipitation with the cadmium in Stage 3 prevents coagulation of the cadmium into metallic balls and facilitates filtering; second, during the cadmium circuit leach (Section 5) arsenic is precipitated or otherwise eliminated, and third, its presence insures a minimum of zinc and cadmium in the copper residue.

If no copper is in the leach solution, sufficient sulphated copper residue is added to give the desired content. Sulphated copper residue is made by mixing copper residue and sulphuric acid and storing in heaps for one or two days.

Approximately 30 min. after the addition of the calculated amount of zinc dust, a further test is taken to determine copper in solution, and if necessary further additions of zinc dust are made.

Agitation is continued for another hour after which solids are allowed to settle for 3 to 4 hr when clear solution is decanted and pumped to the cadmium precipitating tank. (See Section 3.)

The remaining pulp is agitated, air lifted to a wooden storage tank and filtered in a small Moore filter unit.

A cake of about ½ in. thickness is formed in 20 min. and washed with water until relatively free of zinc and cadmium.

The filtrate and washings are pumped by wet vacuum pumps to the cadmium precipitation tank containing the decanted leach solution. The filter cake is discharged to a hopper and fed to an oil fired rotary drier 15 ft long and 3 ft 9 in. diam consisting of a mild steel shell lined with 10 ga stainless steel sheet and fitted with suitable angle lifters.

The dried copper residue is bagged for shipment to a copper refinery at Port Kembla in New South Wales.

## Metallurgical and Operating Data

Average figures for year ending June 30, 1948.

### CADMIUM-COPPER PRECIPITATE

6.85 tons treated per day.

### ASSAY

| | |
|---|---|
| Cd | 10.85 per cent |
| Cu | 6.7 per cent |
| Zn | 33.6 per cent |
| Pb | 0.6 per cent |
| Ag | 2.30 oz per ton. |
| Cadmium extracted by leaching | 98.7 per cent |
| Copper solubility | 68.5 per cent |
| Zinc dust used per ton ppte. leached | 269 lb |
| Limestone used per ton ppte. leached | 25 lb |
| Copper residue factor | 12.8 per cent |
| Copper residue made per filter cake | 921 lb |
| Wash displacement | 1.83 |

### COPPER RESIDUE ASSAY

| | |
|---|---|
| Cu | 46.5 per cent |
| Cd | 1.07 per cent |
| Zn | 5.85 per cent |
| Pb | 6.0 per cent |
| Ag | 18 oz per ton. |

## 3. Precipitation of Cadmium

The precipitation tank is identical in construction to the leach tank previously described except that no decantation hose is fitted and air agitation is not provided.

To the decanted solution, filtrate, and washings derived from the 8000 gal leaching operation described in Section 2 about 600 lb of zinc dust is added after agitation has commenced. Filtered samples of the solution are tested with hydrogen sulphide from time to time and further smaller additions of zinc dust are made until only a trace of cadmium remains.

Approximately 45–60 min. later, if a similar test indicates a satisfactory cadmium content, the pulp is filtered in two 27 in. Dehne filter presses and the filtrate, known as "Return Solution," after by-passing for a few minutes, passes to a storage tank prior to its return to the zinc plant circuit for the recovery of its zinc and cadmium contents.

When the filter presses are full of precipitate, pumping is stopped and a water wash given until a specific gravity of 1.025 shows that the precipitate is almost free of zinc sulphate.

After drying with compressed air the washed precipitate is discharged to hoppers over a drying and oxidizing hearth.

## Metallurgical and Operating Data

Average figures for year ending June 30, 1948.

| | |
|---|---|
| Zinc dust efficiency | 58.1 pct |
| Cadmium in return solution | 1.08 gpl |

## 4. Oxidation and Grinding of the Precipitated Cadmium

The oxidizing hearth is of brick construction with a hearth of cast iron plates approximately 11 by 9 ft mounted so that gases from an oil burner first pass under the hearth and then over the precipitate which, when dropped from the hoppers above, is raked evenly over the hearth to a depth of 4 to 6 in.

As the precipitate oxidizes readily, a maximum gas temperature of 300°C is set at the rising flue from under the hearth to above the charge but rarely is this limit necessary. Hand rabbling proceeds at intervals until the color of the precipitate indicates that oxidation is complete, at which stage the material is discharged by hand rakes to a ventilated hopper from which the precipitate is screw fed to a mild steel ball mill 4 ft long and 2 ft 6 in. diam loaded with 1½ and ¾ in. steel balls. Cadmium cell feed solution is added to produce a reasonably thick mill discharge which is stored in a wooden tank ready for air lifting to the leach tank (Stage 5) when required.

For ventilation purposes, a fan handling 10,000–15,000 cfpm is connected to the hood over the oxidized precipitate hopper and to a hood over the mill feed screw discharge point. The dust laden air is delivered to the base of a water irrigated wooden scrubbing tower mounted over a concrete sump from which the water is recirculated by means of a pump while the settled pulp is withdrawn at intervals and pumped to the leach tank (Stage 5).

## Metallurgical and Operating Data

Average figures for year ending June 30, 1948.

### CADMIUM PRECIPITATE

| | Pct |
|---|---|
| Total cadmium | 69.3 |
| Acid sol. cadmium | 68.5 |
| Zinc | 5.5 |
| Oxidation of cadmium in ppte | 97.7 |

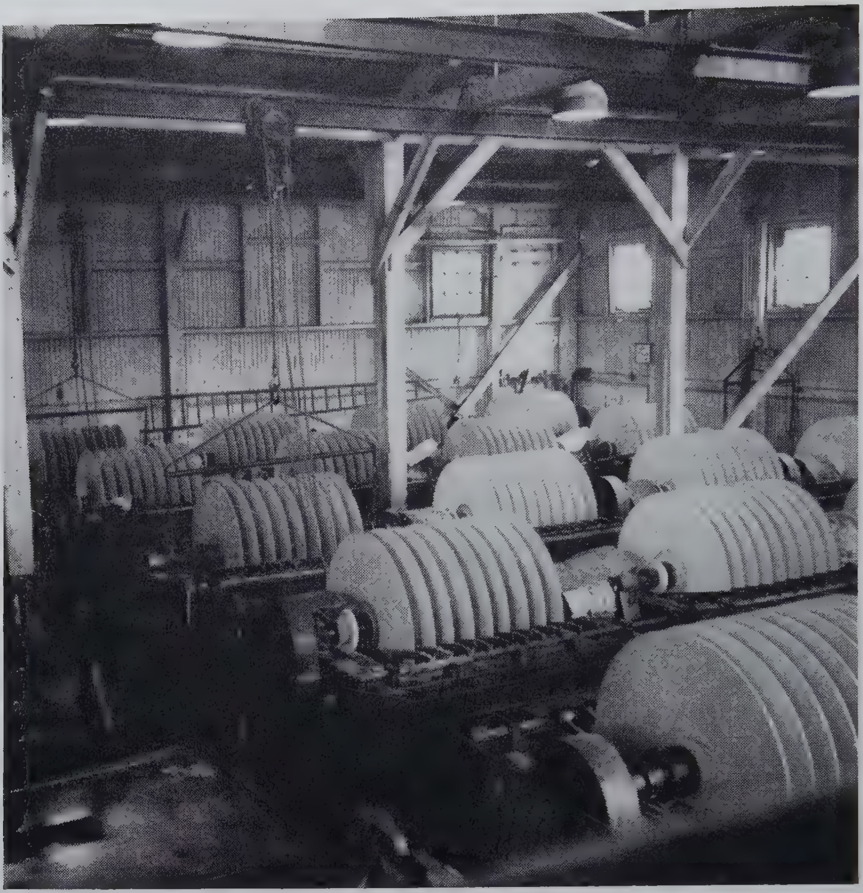

FIG 2—Cell room.

## 5. Leaching and Purification

Variations in the sulphuric acid content of the leach solution are made from time to time in order to hold both the cadmium content and the volume of the cell feed circuit reasonably constant.

If both are about normal, leaching is done with normal cadmium cell spent electrolyte but if the cadmium content is low, the cell spent electrolyte is fortified 10 to 20 g sulphuric acid per liter. If the volume needs increasing, approximately 600 gal of spent electrolyte are supplemented with 800 gal of water and the whole acidified to 150 g sulphuric acid per liter.

In all cases the volume is 1400 to 1500 gal, and the subsequent leaching operation is the same.

Leaching of the ground cadmium precipitate pulp is carried out in a mechanically agitated lead lined tank, having a working capacity of 2400 gal and ventilated by the suction fan mentioned in Stage 4.

The desired volume of leaching solution having been run to the leach tank, pulp from the storage tank is charged until the acidity of the solution is approximately, but not less than 10 g sulphuric acid per liter.

A sample of the pulp is filtered and tested for copper by the sodium–sulphide method (see Appendix 2) and if an excessive amount of copper is present, it is reduced by the addition of unoxidized cadmium precipitate.

Leaching is continued until the acidity is reduced to 1–2 g sulphuric acid per liter when tests are made for copper and arsenic (Gutzeit's Test) and if present, more unoxidized precipitate is added. Agitation is continued for 1 hr after copper and arsenic have been reduced to 0.5 and 0.1 mg per liter respectively and if, after neutralizing with hydrated lime, a further test for arsenic is found satisfactory, the pulp is pumped to a Kroog filter press fitted with 36 by 36 by 1⅛ in. thick frames and plates.

The filtrate is bypassed to the leach tank until free from solid particles as indicated by filtering 500 cc through filter paper and when clarity is satisfactory the filtrate is diverted to one of two lead lined wooden storage tanks each of 3200 gal capacity, where, if necessary, water is added to reduce cadmium to the desired content of 150 g per liter.

By discarding spent electrolyte to the original cadmium-copper precipitate leach and rebuilding the circuit with fortified spent electrolyte and water leaches the impurities are controlled to 30–40 g zinc, 0.7–0.8 g iron and 30–35 mgm chlorine per liter.

The residue collected in the Kroog press during filtering of the cadmium leach pulp, is returned to the cadmium-copper precipitate mixer (Stage 1).

## Metallurgical and Operating Data

Average figures for the year ending June 30, 1948.

| | Pct |
|---|---|
| Cadmium extraction from acid soluble cadmium in ppte. by leaching | 92.5 |
| Cadmium extraction from total cadmium in ppte. by leaching | 89.2 |
| Cadmium leach residue factor | 25.8 |
| Cadmium leach residue | |
| Assay—Cd | 28.7 pct |
| Cu | 31.9 pct |

| | | |
|---|---|---|
| Sulphuric acid used per ton cadmium dissolved | 0.287 | tons |
| Zinc dust used per ton cadmium dissolved | 2470 | lb |
| Hydrated lime used per ton cadmium dissolved | 56.3 | lb |

**FEED SOLUTION ASSAY**

| | | |
|---|---|---|
| Cd | 150.7 | gpl |
| Zn | 37.55 | gpl |
| Fe | 0.79 | gpl |
| Mn | 2.35 | gpl |
| Cl | 30 | mgpl |
| Cu | 0.82 | mgpl |
| As | <0.1 | mgpl |

## 6. Electrolysis

The cell room contains 20 cells arranged in five rows of four cells, each of which is of 3 in. timber, lined first with 8 lb lead and then with 2 in. of a 40 pct sulphur—60 pct sand mixture which has given good service as only 2 linings have failed in 25 yr. Internal dimensions of the cells, which have a volume of 208 gal, are 5 ft square and 2 ft 6 in. deep while the cross-section is semioctagonal.

The lead of the 10 half-round, 23 in. radius anodes contains 0.01 pct silver to give added rigidity and extend the 4 yr life to 5 yr.

Mounted on a 3 in. diam mild steel shaft and separated at 5½ in. spacing by rubber covered aluminum sleeves are 9 aluminum cathodes, 4 ft diam and ¼ in. thick, each of which has a submerged surface area of 8 sq ft and lasts 7 to 8 yr. To enable the stripped cadmium sheet to be readily broken into four conveniently sized quadrants, each side of the cathode is radially grooved at 90° spacing to a depth of 1/32 in. Before assembly, each cathode is given a matte surface by scrubbing with a steel wire brush and sandstone.

Once each year the cathode assembly is dismantled, inspected, cleaned and, if necessary, faulty parts replaced.

Cathodes are rotated at 10 rpm by suitably driven link chains through gearing from which the cathode assembly may be disengaged without stopping the driving mechanism. Electrically the cells are arranged in series and current is supplied by two motor driven parallel connected generators rotating at 960 rpm and each capable of supplying 650 amp over a range of 25 to 70 volts.

Anode bus bars of 1¼ in. square copper are arranged to give the anode head bars an edge contact and between adjacent cells is a hinged section for short circuiting a cell when cathode assemblies are removed for stripping.

The series circuit is made complete by means of a 9 in. diam brass collector keyed to the cathode shaft and contacting brushes connected by copper cable to the following anode bus bar.

Cell voltage is approximately 3.5 volts per cell.

Feed solution containing 150 g cadmium per liter gravitates from the feed storage tanks through iron pipes of uniform length flanged together for ease of cleaning.

Each cell has a separate feed pipe through which the rate of feed is controlled to hold the acidity of the cell solution at 85–90 g sulphuric acid per liter. Titrations with caustic soda using Congo Red indicator are made every four hours.

Spent overflows from each cell to a launder common to each row and gravitates to a storage tank.

Glue solution containing 0.14 lb glue per gal is added every four hours at a rate equivalent to 2½ to 3 lb per ton cadmium deposited. During deposition, the cadmium surface tends to roughen by the formation of "trees" which are wiped off at intervals with a slotted wooden tool to which rubber strips are attached to make contact with each face of the cathode simultaneously. Trees are cleaned from the cells monthly and returned to the tube mill grinding the original cadmium-copper precipitate.

Stripping periods are either 48 or 96 hr depending on the current density demanded by production. When the current density on the immersed cathode surface is between 10 and 12 amp per sq ft quite a reasonable current efficiency is obtained and the deposit adheres to the cathode, but, when the current density is higher, the stripping period is reduced to 48 hr as beyond this time the current efficiency is found to decrease and the deposited cadmium sheets tend to become detached.

The production of cadmium is not regular owing to variation in the amount of incoming cadmium, consequently both the number of cells used and the current density are varied, but it is aimed to operate at 10 to 12 amp per sq ft; however, at times a higher density is necessary. When the deposit is about to be stripped, the cell concerned is short circuited by means of the hinged section of the anode bus bar, hooks suspended from a bridle of convenient length are attached to fittings on the cathode shaft and the whole cathode assembly is lifted by means of a travelling chain block and lowered on to trestles at the end of the cell row.

The deposit is removed by means of stripping knives, broken into quadrants, stacked almost vertically in portable racks, weighed and transferred to the melting section.

Before returning the assembly to the cell, each aluminum cathode is hosed, scrubbed with a stiff bristle brush and, if necessary, given a light rubbing with sandstone. (Fig 2.)

### Metallurgical and Operating Data

Average figures for year ending June 30, 1948.

| | | |
|---|---|---|
| Average current | 800 | amp |
| Current efficiency | 88.7 | pct |
| Current density | 11.0 | amp per sq ft |
| Cadmium "trees" produced | 6.11 | pct of cathode deposited |
| Number of cells in use | 17.6 | |

**DISCARD SOL. ASSAY**

| | G per Liter |
|---|---|
| Cd | 68.2 |
| Zn | 37.2 |
| $H_2SO_4$ | 84.5 |

## 7. Melting, Casting and Packing

The cadmium sheets are melted, under a cover of molten rosin, in an oil fired cast iron pot, having a capacity of approximately 2500 lb cadmium.

The molten cadmium is handled from the pot to the molds in a mild steel ladle, the pouring spout of which is in the form of a pipe reaching almost to the bottom to prevent dross or flux entering the mold.

Cadmium is cast in various shapes for commercial purposes. (See Appendix 3 and Fig 3.)

Molds are either lubricated with stearin or No. 3 shell grease or sprayed with a fine mist of dilute sulphuric acid in order to give a clean bright surface to the castings which after inspection are packed in Tasmanian oak cases in which are inserted sheets of waxed paper and cardboard to keep the castings from contact with the wood.

Each case is banded with ⅜ in. wide banding iron and stamped with particulars of type of casting, gross and net weights, lot and case numbers.

Periodically dross is ladled from the surface of the molten cadmium in the melting pot into mild steel trays and after cooling and weighing is ground in a Berdan grinding pan from which a stream of water carries off the slime to a settling pond, the overflow from which passes into the cadmium-copper precipitate pulp circuit.

The dross slime, collected in a settler,

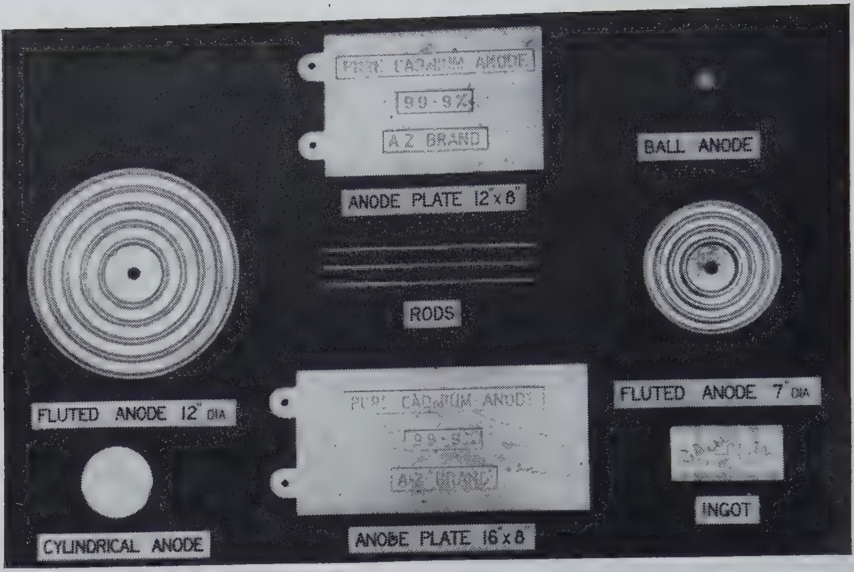

FIG 3—Cadmium castings.

is fed to one of the zinc plant roasting furnaces and eventually returns, via the zinc circuit, to the cadmium plant.

Clean cadmium prills are removed from the pan, dried, weighed and remelted.

It is planned to replace the rosin flux with one of three parts ammonium chloride and eight parts zinc oxide which, in addition to enabling all cell trees to be remelted direct, will dispense with grinding and the return of the dross slime through the zinc circuit and as a result cadmium losses will be reduced.

The melting furnace is enclosed in a mild steel hood from which rosin vapor is exhausted, but before being discharged to atmosphere, passes in series through three vertical, wire packed mild steel cylinders in which approximately 60–70 pct of the rosin is condensed for further use.

## Metallurgical and Operating Data

Average figures for year ending June 30, 1948.

| | Pct |
|---|---|
| Melting efficiency (including returned prills) | 95.91 |
| Cadmium prill recovered from dross | 7.56 |
| Cadmium in dross slime to roasting plant | 1.35 |
| Unaccounted melting loss | 2.74 |
| Rosin used (pct cathodes melted) | 3.02 |
| Rosin distillate recovered (pct tot. rosin used) | 68.3 |

### CADMIUM ASSAY

| | Pct |
|---|---|
| Cd | 99.9590 |
| Cu | 0.0009 |
| Zn | 0.0263 |
| Pb | 0.0136 |
| Fe | 0.0002 |

### METAL DISTRIBUTION

| | Pct |
|---|---|
| Cd as metal | 79.68 |
| Cd in return solution | 11.13 |
| Cd in copper residue | 1.27 |
| Unaccounted loss | 7.92 |
| | 100.00 |

## Acknowledgment

The author desires to express his appreciation to the Directors and Management of the Electrolytic Zinc Co. of Australasia Ltd. for permission to publish this paper.

## Appendix 1

### COPPER TEST—CADMIUM-COPPER PRECIPITATE LEACH

#### *Reagent*

Standard comparison solution containing 0.5 gpl copper.

#### *Test*

Place 100 cc of standard solution in one comparison tube and 100 cc of filtered leach solution in a similar tube. Compare the blue color against a white background.

1. If leach solution is less blue than the standard but is still perceptibly blue, the leach can be finished.
2. If no blue is perceptible add sulphated copper residue in 100 lb lots until the standard blue is obtained.
3. If the leach solution blue is more intense than that of the standard solution the excess copper must be removed by zinc dust and the quantity required is estimated as follows:

Determine the quantity of filtered solution which, when diluted to 100 cc with water will match the blue of the standard solution. The quantity of zinc dust required per 1000 gal of leach can be determined from the following formula:

$$\text{Zinc dust per 1000 gal} = \frac{V}{100}\left(\frac{100}{2T} - 0.5\right)$$

$T$ = Vol. solution (cc) used in test.
$V$ = Vol. leach solution in the leach tank.

## Appendix 2

### COPPER TEST—CADMIUM PRECIPITATE LEACH

#### *Reagent*

Sodium sulphide solution (saturated).

#### *Test*

Take 100 cc of filtered leach solution in a stoppered bottle, add 5 drops of sodium sulphide solution, shake vigorously and filter.

The color of the precipitate on the paper is compared with a standard and must be inspected by the shift boss before filtering is permitted.

## Appendix 3

### CADMIUM SHAPES

| | Weight |
|---|---|
| Rods—12 in. long, 5⁄16 in. diam | 4½ oz |
| Ingots—6 by 3 by ⅜ in. | 2 lb |
| Ball anodes—2 in. diam | 1¼ lb |
| Anode plates—12 by 8 by ¼ in. | 9 lb |
| Anode plates—16 by 8 by ¼ in. | 11 lb |
| Fluted anodes—12 in. diam | 16¼ lb |
| Fluted anodes—7 in. diam | 7¾ lb |
| Cylindrical anode—4 in. diam by 1¼ in. | 5¾ lb |

# Electrolytic Zinc at Risdon, Tasmania. Major Changes Since 1936

S. W. ROSS*

## Introduction

In 1936 a description of the plant (Fig 1) and process employed by the Electrolytic Zinc Co. of Australasia Ltd. for the recovery of zinc from zinc concentrate by the electrolytic process was prepared.†

During the twelve years which have elapsed since the preparation of the earlier paper, several major changes in the metallurgy of the process have been introduced. It is the purpose of the present paper to give a general description of these changes and thus to bring up to date the description of the plant and process.

## Summary

The major changes in Risdon practice since 1936 have been:

1. Replacement of two stage roasting by a preliminary roast followed by the flotation of all the leach residue and the roasting of the flotation concentrate.
2. Screening of all calcine fed to the pachucas.
3. Continuous leaching of calcine and improved classification of pachuca discharge.
4. Close control of hydrogen ion concentration during purification for iron removal.
5. Recovery of cobalt as a good grade oxide.
6. Production of part of the zinc output in the form of "four nines" metal (99.99 pct purity).
7. Closer spacing of electrodes thus increasing the potential output of cathode zinc per cell by 50 pct.

Changes which are in prospect and for which construction work is proceeding at the present time involve the starting up of:

1. Two suspension roasters.
2. A contact acid plant to produce 150 tons‡ of acid per day and replacing the existing Mills Packard chamber plant.
3. Extra power station capacity to permit greater current flow to existing cell room units. This will increase the output of cathode zinc from about 245 to 290 tons per day.

Plans for the future envisage the building of an ammonium sulphate plant, the first unit of which will produce about 50,000 tons per year, and improved treatment of zinc plant residue for the recovery of zinc, lead and other metals.

At the end of this paper tables of metallurgical data are presented relating to the year ending June 30, 1948.

## Details of Changed Practice Output

In 1936 the production of cathode zinc amounted to about 200 tons per day. This has since been increased to about 245 tons per day while plant extensions are practically complete which will permit of an output of about 290 tons per day in the near future.

## Roasting Division

### ROASTING POLICY

A major change has occurred in the roasting policy. Twelve years ago the method in use was to carry out a two stage roast in the first stage of which sulphide sulphur was reduced to about 6 pct. The pre-roast calcine was re-roasted in modified Leggo furnaces using coal as fuel, sulphide sulphur being reduced to about 0.8 pct. The whole procedure was described on pp. 482–491 of the earlier paper.

Although this roasting procedure had certain advantages it possessed some distinct disadvantages. For instance, it appeared uneconomical to heat up the entire input of pre-roast calcine to roasting temperature by the expenditure of fuel in order to oxidise a few percent of sulphide sulphur. It was argued that if the pre-roast calcine were leached and a process could be developed for the recovery of a zinc sulphide concentrate from the leach residue, this concentrate, small in weight compared with the pre-roast calcine, would probably roast autogenously, thus virtually eliminating the expenditure of fuel as well as greatly increasing the weight of sulphur oxidised per square foot of furnace hearth area.

The obvious method of producing a suitable concentrate from leach residue was by flotation. It will be recalled (see p. 495 of the earlier paper) that when two-stage roasting was practised the leach residue was classified, the granular fraction was ground and floated while the slime fraction was thickened, filtered and dried ready for shipment to a lead smelter. This process worked quite successfully. However, when trials were made of leaching a calcine carrying several percent of sulphide sulphur the granular fraction still floated well, but the slime fraction carrying 8–10 pct sulphide sulphur yielded very poor results when subjected to flotation. This fact held up the application of "pre-roast" leaching for many years. However, successful flotation of the slime fraction of leach residue was finally achieved and in August 1940 the slime flotation plant began operation, while the leach-

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‡ Throughout this paper the long ton of 2240 lb and the Imperial Gallon are used.

San Francisco Meeting, February 1949.

TP 2524 D. Discussion of this paper (2 copies) may be sent to *Transactions* AIME before May 15, 1949. Manuscript received October 1, 1948.

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† W. C. Snow: Electrolytic Zinc at Risdon, Tasmania, AIME *Trans.* 121, 482.

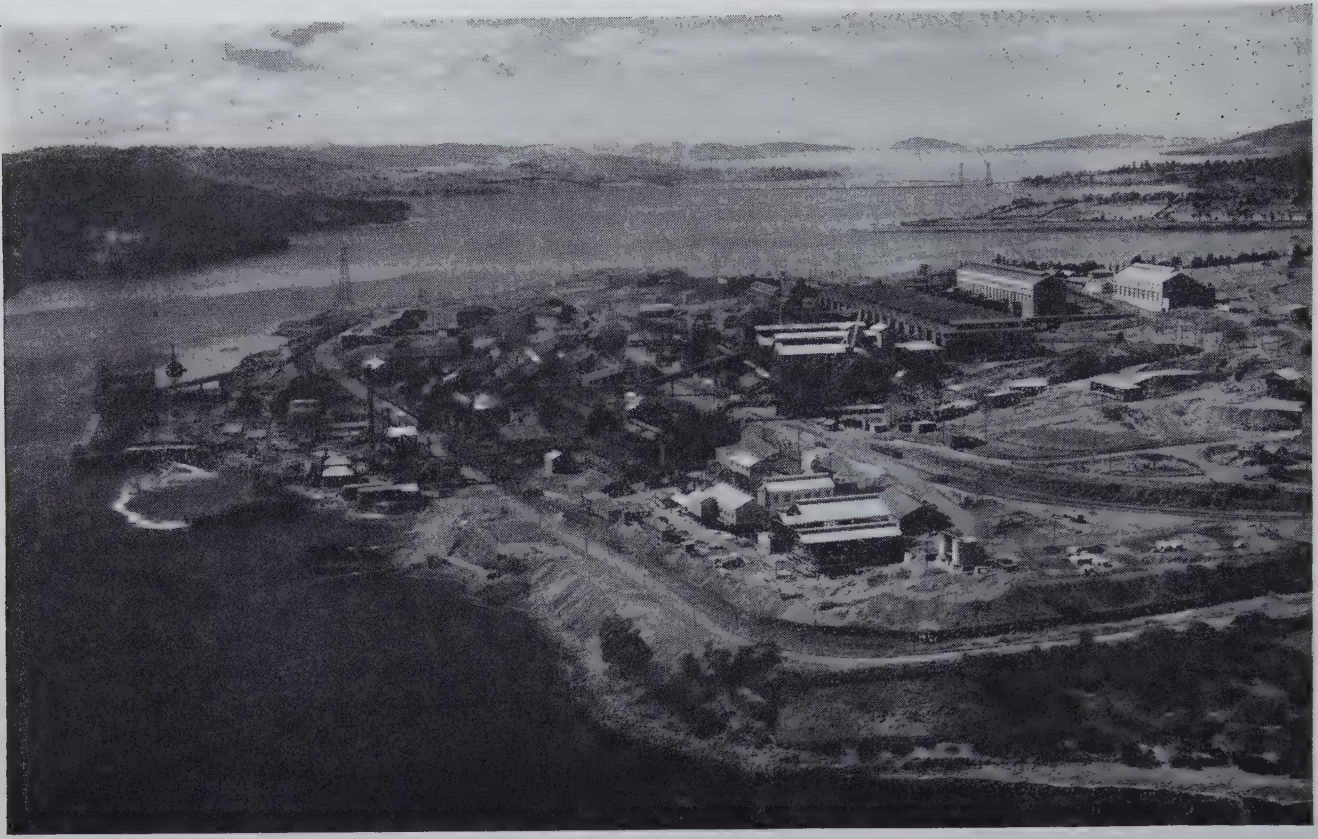

FIG 1—General view of works.

ing of pre-roast calcine became an accomplished fact. A description of the flotation section will be given later in the present paper. Calcine leached at the present time carries from 5–6 pct sulphide sulphur while the mixture of concentrates from the granular and slime flotation sections carries about 22–24 pct sulphide sulphur. This mixed concentrate is roasted for the most part in modified Skinner furnaces.* The flotation tailing, carrying 1.5–2.5 pct sulphide sulphur, is filtered and dried and becomes the final zinc plant residue. The loss of sulphide sulphur in residue is little higher than it was when two stage roasting was practised.

It is not proposed to set out the arguments of single stage roasting to low sulphide sulphur versus the present method of roasting with intermediate flotation. However, it should be stated that the present method permits of high roasting rates and in some of the newer furnaces an oxidation rate of 12–13 lb sulphur per square foot of hearth area per day has been achieved without the use of any fuel. With a very small fuel addition (less than 0.5 pct of oil) the figure has risen to 14–16 lb.

### CALCINE SCREENING SECTION

The introduction of continuous leaching, described later in this paper, made it imperative to screen the calcine on its way to the Leaching Division. Preliminary trials of continuous leaching when using unscreened calcine were unsatisfactory because many of the larger lumps would not move from pachuca to pachuca and accumulated in the first and second units of the series. A plant for the screening of all calcine entering the Leaching Division was, therefore, built and this has removed the trouble.

The screening station consists of two vibrating screens each 8 × 3 ft and fitted with ¼ in. wire mesh. The oversize falls to a bin and is fed intermittently to a swinging arm breaker. A bucket elevator returns the crushed oversize to the screens.

## Leaching and Purification Division

### LEACHING

The leaching of calcine and the purification of the resulting solution were described fully in the earlier paper (see pp. 491–510). No modification of the fundamental principles of this division has occurred but many important changes have taken place in details.

The batch leaching of calcine was described in the earlier paper. Although quite successful in operation, batch leaching employs a relatively big labor force, it uses the pachucas inefficiently in that much lost time occurs in filling and emptying while the discharge of pulp at a low level loses head and under Risdon conditions makes improved classification of pachuca discharge difficult. These considerations coupled with the somewhat restricted space available for building new pachucas for increased production led to the introduction of continuous leaching in 1945.

Ten pachucas, each 12 ft diam and 34 ft stave and arranged in two rows of five, were previously employed in batch work (nine in 1936). These have been so connected that all ten may be used together if so desired, but any one or more can be cut out for repairs. In normal practice the ten units are divided into two groups of five each and one set only is in use at a time. It has been found that five pachucas, used in continuous flow, leach as well as ten employed on batch work.

Screened calcine enters a small bin of

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* See contemporary paper, J. A. B. Forster: Autogenous Roasting of Low Grade Zinc Concentrate in Multiple Hearth Furnaces at Risdon, Tasmania.

80 tons capacity which feeds an 18-in. belt running centrally above and between the two rows of pachucas. From this belt calcine is fed continuously by means of a tripper to the head pachuca while spent solution from the electrolytic division is fed to the same pachuca.

At the top of each column and placed to one side is a swinging launder so arranged that it picks up part of the discharge from the top of the column and transfers it to a short launder feeding the next pachuca. This equipment permits the coarser particles rising in the column to be transferred to the next pachuca at the same time maintaining the same pulp level in all pachucas of the series. The discharged pulp flows to a launder placed beneath the operating floor and running between the two rows. From time to time scuttling of one or more pachucas becomes necessary and a low level launder—used previously for batch leaching—takes the discharge.

The flow of solution through the pachucas for the present output of about 245 tons of cathode zinc per day amounts to about 800,000 to 1,000,000 gal per day while 600–700 tons of calcine is leached. The spent electrolyte carries up to 100 g acid per liter and this is reduced to 1.5–2.0 g per liter before discharge.

Continuous leaching has proved advantageous in that it is simpler, saves labor, uses 35 psi air in place of 90 lb air, the equipment is utilised more efficiently while improved classification and flotation results have been made possible.

## CLASSIFICATION AND THICKENING OF PACHUCA DISCHARGE

The classification of pachuca discharge has been improved by the addition of a V shaped box 42 ft 9 in. long, 10 ft wide at the top and 10 ft deep. The pachuca discharge enters at one end at the top and flows the length of the box. The fine fraction of the solids passes over the lip and enters five 50 ft diam by 15 ft stave Dorr thickeners. The granular fraction, discharged from the bottom of the V shaped box through six spigots, is dewatered in six duplex Dorr classifiers (see item 2 p. 494 of the earlier paper). The underflow from the classifiers is delivered to the granular flotation section while the overflow from the classifiers joins that from the V box on its way to the thickeners, where the pulp is thickened to a specific gravity of about 1.8. The thickener underflow is elevated to pulp holding tanks whence it is delivered to the slime flotation plant.

## FLOTATION OF LEACH RESIDUE

The granular flotation section described on p. 495 of the earlier paper remains unchanged in principle but has been enlarged, while improved classification has been achieved by the addition of a 12 ft diam cone dealing with the tailing. The underflow from the cone is dewatered in a small simplex Dorr classifier and returns to the tube mills for regrinding. The overflow from the cone goes to the five primary thickeners and so granular tailing normally joins the feed to the slime flotation section.

The slime flotation section consists essentially of three main parts, pulp preparation, flotation, and thickening of concentrate and tailing.

Pulp preparation consists of two main steps:

1. A 12 ft diam × 12 ft stave tank mechanically agitated receives the slime pulp from the leaching division. This tank is normally kept full. Spent electrolyte is added to maintain an acidity of about 1.75 g per liter. Finely ground manganese cell mud is added. The supply of pulp, acid and manganese dioxide is more or less continuous to this tank. An air lift elevates the pulp to a bucket feeder which consists of eight stainless steel buckets attached to a 3 ft 6 in. diam wheel. The discharge from the buckets is divided by a movable cutter, one part going forward for flotation and the other part returning to the pulp tank. In this way a continuous and constant feed rate is maintained.

2. The discharge from the bucket feeder enters the first of five air agitated processing boxes each 4 ft square. Finely divided limestone pulp is fed to the first box for neutralising excess acid. Then cresylic acid and eucalyptus oil are added and finally the pulp is diluted with circuit solution to a pulp density of about 3–3.5 lb solids per gallon. A pulp density recorder controller maintains the pulp at the required specific gravity.

The processed pulp then goes forward to the flotation boxes. There are sixteen boxes arranged in two rows of eight. Each box is 3 ft 6 in. × 3 ft 6 in. × 5 ft 2 in. deep. The impellers, 18 in. in diam, are made of stainless steel and revolve at 370 rpm. Each pair of impellers is driven by a single vertical 12 hp motor, while air from a Connorsville blower is supplied through an adjusting valve to each box. Each row of eight boxes has a common pulp level since each partition between boxes has an aperture 2 ft wide × 6 in. deep cut 8 in. from the bottom. The froth level is controlled by inserting riffles in slots. No mechanical scraping is necessary since the froth flows very freely.

The sixteen boxes are divided into three groups, namely, five rougher concentrate, three cleaner concentrate and eight scavenger. Potassium xanthate is added to the pulp leaving the rougher boxes and entering the scavenger boxes.

The tailing flows to two 50 ft diam × 15 ft stave Dorr thickeners. The overflow is returned to the flotation circuit while the thickened pulp is filtered and dried as described on pp. 496 and 497 of the earlier paper. Oil has replaced coal for firing the driers.

The combined concentrate from the two flotation sections is thickened in two 50 ft diam × 15 ft stave Dorr thickeners. The overflow is returned to the main zinc plant circuit while the underflow is filtered in two six-leaf 8 ft 6 in. diam disc filters. The discharge from these filters is not washed and is forwarded by belt conveyor for roasting.

It has been found that the zinc content of the circuit solution in the slime flotation section is of importance and an endeavor is made to keep zinc in the range 80–90 g per liter. This is done by bringing washings and other low zinc tenor liquors into the flotation section and using them for pulp dilution.

## IRON PURIFICATION

The overflows from the five primary thickeners dealing with pachuca discharge combine and the solution goes forward for the removal of iron, silica, arsenic and antimony, by the addition of finely divided limestone. This procedure was described on pp. 497 and 498 of the earlier paper and the basic principles remain unchanged. Considerable refinement in detail has taken place however, and this has effected a marked improvement in the filtering properties of the precipitate while the effectiveness of purification has been increased considerably.

In 1936 there were four 28 ft diam × 12 ft stave agitators in series. An extra agitator has been added and each of the first three in the series has been divided into two by building a partition across a diameter in order to reduce the effect of short circuiting. The first agitator receives thickener overflow at about 1.5 to 2.0 g acid per liter. Here ground manganese mud is added for the oxidation of iron. During the leaching of preroast calcine up to 1.0 g iron per liter is dissolved and part of this is reduced by sulphides to the ferrous state and up to 300–400 mg of ferrous iron per liter may be present. The bulk of this is oxidized in the first agitator.

The conditions in the second agitator of the series are critical and it is here that considerable improvement has occurred. It was discovered that both the physical state and the chemical composition of the precipitate resulting from the addition of limestone are profoundly altered according to the hydrogen ion concentration at which precipitation occurs. It has been determined that if the pH of the pulp in the precipitating tank is maintained at a figure greater than about 4.0 the physical state of the resulting precipitate is such that it filters rapidly while the iron is present almost wholly as ferric hydroxide with but small formation of basic ferric sulphate.

The effect of this procedure on the filtering rate of the ensuing pulp is remarkable. If limestone is added to the acid solution so that the pH slowly rises to the critical figure the time of filtering the pulp under otherwise similar conditions will be about five times as long as it is if the pH is maintained at about 4.0 during precipitation. Similar results are obtained if the neutralising agent is finely ground calcine instead of limestone.

The control of pH is achieved by the continuous addition of finely ground limestone and the intermittent return to the purifying tank of every second primary filter cake. A pH indicator and also a recorder have been installed and it is proposed to add a controller to the recorder.

No material change has occurred in the amount of silica removed during iron purification but the recognition of the part played by silica during purification has been of importance. In the course of leaching traces of germanium are dissolved, and, if this element is not removed almost completely, it increases the reversion of cadmium during the filtration of copper cadmium precipitate and reduces current efficiency during subsequent electrolysis. It is believed that the presence of at least 1.0 g per liter and preferably about 1.3 g per liter of silica in the solution entering the iron purification tanks is effective in controlling germanium.

The filtration of iron precipitate was described in detail on pp. 498–501 of the earlier paper. The number of leaves per filter basket has been increased in the ratio of five to four while a rest period in hot water has been introduced to remove incrustations of gypsum from the canvas. These factors coupled with the greatly improved filtering properties of the precipitate have enabled the section to handle with ease the solution flow equivalent to 245 tons of cathode zinc per day, whereas previously, difficulty was often encountered when the output was only 200 tons. It is anticipated that existing equipment will handle without difficulty the solution flow when output increases to 290 tons of cathode zinc per day.

## COPPER CADMIUM PURIFICATION

The removal of copper and cadmium was described on p. 501 of the earlier paper. The section has been enlarged somewhat and the general results improved. Eight purifiers are now employed and filtration takes place in 3 × 3 ft Dehne presses as previously. The solution for purification now contains about 90–120 mg copper and 150–180 mg cadmium per liter. The zinc dust charge is normally 250–300 pct of theoretical requirements.

The filtration of the discharge from the purifiers has been improved by feeding both ends of the presses which are now fitted with 68 frames 1½ in. thick built up from mild steel. The improved feeding arrangement coupled with the 1⅛ in. frames permits the filling of a press in approximately 12 hr. Control of germanium during iron purification, quicker filling of presses and a greater excess of zinc dust coupled with a constant watch by shift chemists on the cadmium content of press filtrate, have combined to produce a purified solution carrying 1.5–2.5 mg cadmium per liter.

The filter cake is treated for the recovery of metallic cadmium and of copper in the form of a copper rich residue in a separate plant.*

## COBALT PURIFICATION

The method of removing cobalt from solution was described in detail on pp. 501 and 502 of the earlier paper. No change, except in minor detail, has occurred in the method of purification during the ensuing twelve years.

## COBALT OXIDE PLANT

A major change has taken place in the method of disposing of the cobalt precipitate which was previously wasted. Many attempts were made to find uses for this precipitate and to recover economically valuable by-products from it, but all such early attempts ended in failure.

The precipitate after filtration is a mixture of cobalt nitroso beta-naphtholate, gypsum, basic zinc sulphate and unconsumed slaked lime, mixed with zinc sulphate solution. It was discovered that the cobalt nitroso beta-naphtholate would float and if conditions were right, a relatively high grade concentrate could be produced. A plant was, therefore, built and has operated successfully since 1936. One of the features of this process is that the concentrate froth is produced quite readily in the absence of any addition agent.

The cobalt precipitate pulp is transferred from the purification section by pulping it with water and pumping it to the cobalt oxide plant. Two mechanically agitated tanks 9 ft diam × 11 ft stave receive the pulp. These tanks are used alternately, one receiving the pulp one day and the other receiving it the next day. When the day's output of precipitate is transferred, sulphuric acid is added until the acidity reaches about 3 g per liter. Basic zinc sulphate and calcium hydroxide are consumed during a short period of agitation. The pulp contains about 2½ lb of solids per gal and is pumped to the first of a row of ten flotation boxes each 3 ft × 2 ft 9¼ in. × 5 ft deep. The ten boxes all have a common pulp level since the partitions between boxes do not extend to the bottom and leave a gap of 3 in. On the floor of each box is a canvas aerator stretched over a rectangular frame of 1¼ in. copper pipe. Air is supplied to the aerator at a pressure of 1½–2½ psi while the froth level is controlled by riffles fitted into slots. The first box of the series is used as a digester and returned circuit solution is added to bring the pulp density to about one pound per gallon. The next six or seven boxes are used for concentrate production while the last two or three make a middling which is returned to the feed.

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* See contemporary paper. G. H. Anderson: The Recovery of Cadmium from Cadmium Copper Precipitate—Electrolytic Zinc Co. of Australasia Ltd.

The tailing is normally a milky white suspension of fine gypsum crystals in zinc sulphate solution.

The process is very sensitive to the volume of air supplied to the aerators and the flow of concentrate froth must be extremely gentle otherwise gypsum is entrained in it. A normal calcium content of the concentrate is about 0.02 pct but it is very easy to multiply this many times by the use of too much air. Another impurity of importance is iron. If iron escapes precipitation in the iron purification section some of it is later precipitated along with cobalt. The flotation of cobalt precipitate does not differentiate between iron and cobalt so that virtually all the iron present in the precipitate appears in the concentrate.

The concentrate flows to a 9 ft diam × 9 ft stave holding tank whence it is pumped to a Moore filter. The basket consists of six leaves each 4 ft × 3 ft 6 in. After filtration the basket is transferred to a washing tank where thorough washing removes most of the water soluble zinc. The cake is blown off to a hopper from which it is fed to an oil fired hand rabbled reverberatory furnace 20 ft long × 4 ft wide where the organic material is burned off, and a final product of reasonably pure cobalt oxide is discharged from the furnace. This is placed into steel drums ready for the market. During the war years some cobalt sulphate and metallic cobalt were produced for special purposes.

### SOLUTION COOLING

The plant for the cooling of purified solution prior to its being pumped to the electrolytic division which was described on p. 504 of the earlier paper, has been extended by the building of a second cooling tower similar to the one described previously. The two towers are used alternately so that during the cleaning of one tower the other is in use.

## Electrolytic Division

The electrolytic division was described in detail on pp. 511–519 of the earlier paper. Basically, the same procedure is still employed but some quite important modifications have been introduced.

### FOUR NINES ZINC

The specification of the Standards Association of Australia for zinc base die casting alloy sets an upper limit for lead of 0.007 pct. Attempts at Risdon over many years failed to produce zinc conforming to this specification. The best results had been obtained with 1 pct silver lead anodes but the zinc still contained 0.01 pct lead or even more. During the war a considerable demand for high quality die castings developed and renewed efforts were made to meet the specification. Following a suggestion made by Mr. W. H. Hannay of The Consolidated Mining and Smelting Co. of Canada success was achieved by the simple expedient of cooling the electrolyte in cells fitted with 1 pct silver lead anodes to about 28°C. Many thousands of tons of zinc containing about 0.005 pct lead have now been produced by this method and have been used for the production of die casting alloy. There is no production of ingot zinc of this very high grade since all cathodes not used for the manufacture of die casting alloy are melted with the ordinary make of plant zinc. The anodes used are not perforated and conditions of electrolysis are standard except in regard to temperature. Experiments in which the temperature was reduced to 20°C showed no further improvement in the lead content of zinc.

### CLOSER SPACING OF ELECTRODES

In 1936 the cells in the four big units contained 34 anodes and 33 cathodes while the current flow was nominally 12,000 amp. The spacing of anodes center to center varied between 4 in. and 3½ in. in the various units. The urge for increased power efficiency and later for increased output focussed attention on the closer spacing of electrodes. A suitable double cone porcelain spacing insulator was developed and two of these were fitted to each anode. (See Fig 2). In this way it was found possible to insert 45 anodes and 44 cathodes into each cell at 3 in. spacing. The current flow can be increased to 18,000 amp and the output from a single unit increased from about 46 to about 69 tons per day.

At the present time the four big units have all been fitted with rolled copper bus-bars capable of carrying the increased current. However, only two units are as yet supplied with the full power input. The other two units will be supplied as soon as a new converter station, now under construction, is completed.

### ELECTRODES

The size and shape of electrodes are virtually the same as they were in 1936 except that now plain ¼ in. aluminum sheets are used as cathodes.

Twelve years ago the life of a cathode was extended by attaching protective strips of aluminum above solution level. This was effective because maximum corrosion occurred about 1½ in. above solution level. In recent years solution line corrosion has increased markedly possibly related to an increase of fluorine in the electrolyte from about 15–20 mg per liter up to 30–35 mg per liter. Protective strips which give no benefit at the solution line have therefore been discarded but cathode cost per ton of zinc has increased considerably.

Trials of re-rolled used cathodes have

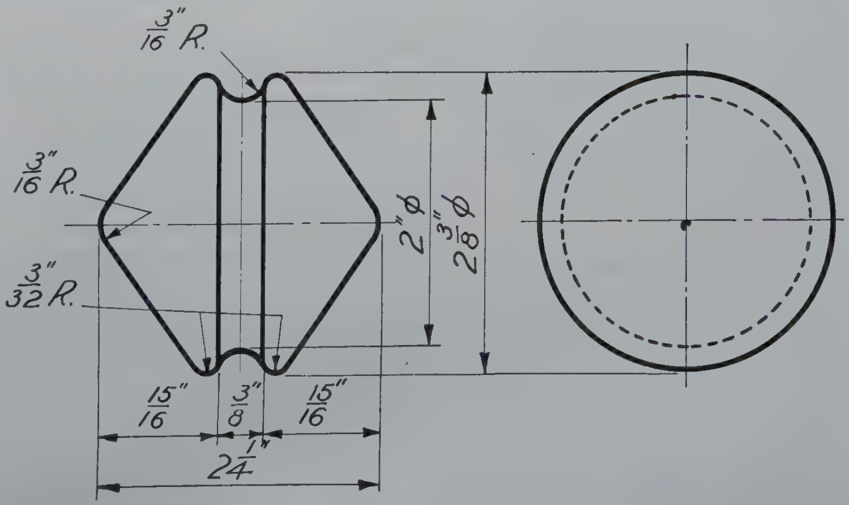

FIG 2—Anode spacing insulator. Glazed porcelain.

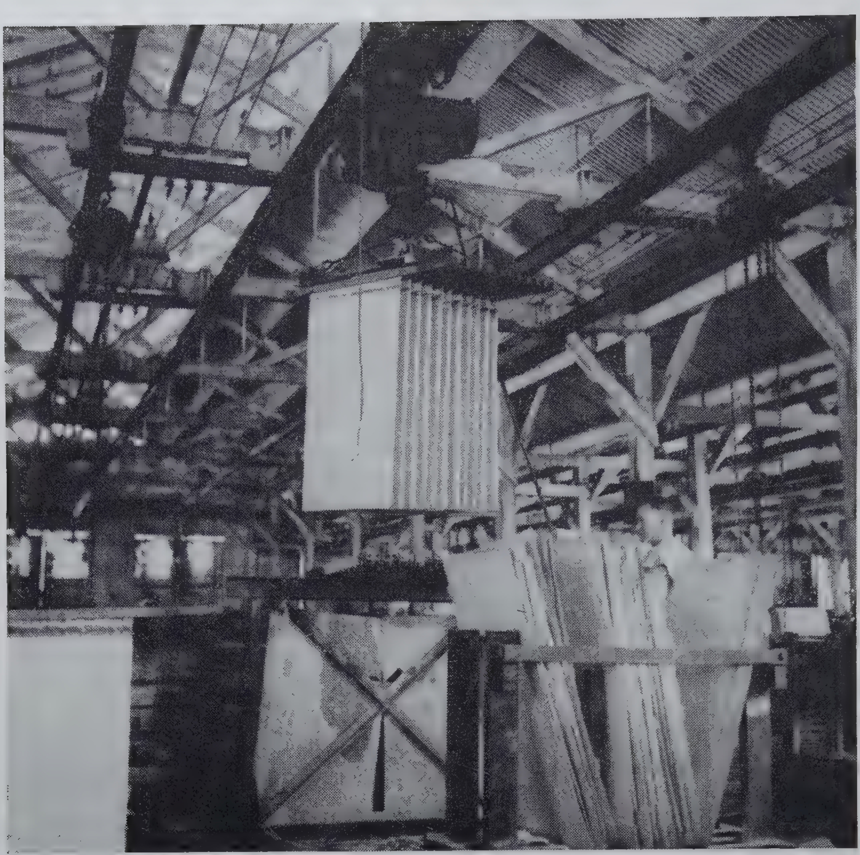

FIG 3—Hoist in action.

been made with only moderate success.

Anodes now contain 0.012 pct silver. This addition has been made to increase the stiffness and to reduce the need for anode straightening. This small addition probably is responsible for a reduction in the lead content of normal cathode zinc to a figure of about 0.012 pct. An interesting minor modification has been made in the treatment of new anodes prior to placing them in the cells. It was discovered that if the anodes were painted with a slurry of cell mud while they were still hot after casting, the conditions of electrolysis were much improved during the first two or three stripping periods. Prior to the introduction of this practice current efficiency was low during the first few stripping periods.

### COOLING OF ELECTROLYTE

The adoption of closer spacing and greater current flow has called for more cell cooling. There is not room for more than about four cooling coils per cell and in these circumstances the temperature of the electrolyte during the hotter months of the year tended to be unduly high. Experimental work has indicated that the greatest yield of cathode zinc per unit of power occurs when the temperature of the electrolyte is about 32–33°C. In practice an endeavor is made to keep the temperature below 35°C.

The demand for a greater extraction of heat from the cells stimulated an investigation into the design and cleaning of the cooling coils described on p. 514 of the earlier paper. The outstanding result of this investigation was the recognition that even when cleaned thoroughly by hand scraping and brushing, a coil quickly lost up to one half of its effectiveness due to the formation of a thin hard scale on the outer surface.

A system of electrolytic cleaning has been developed in which the coils are made cathodic in a dilute solution of sulphuric acid. An input of about 75–100 amp per coil is effective in removing adherent scale during overnight treatment. The efficiency of the coil as a heat remover has been restored to about 90 pct of that of a new clean coil and temperature control of the electrolyte is now not difficult even in the hotter months of the year.

### LIFTING OF CATHODES

The hand operated chain blocks for lifting groups of cathodes for stripping and described on pp. 514–515 of the earlier paper are still in use but at the time of writing this paper a changeover is being made to electrically operated hoists. One of these has been on trial for a long period and has proved very satisfactory. Another twelve are being installed and it is hoped to equip the whole cell room with these hoists—one hoist for every three cascades. (Fig 3.)

### ADDITION AGENTS

The use of about 24 mg glue per liter and 10 mg beta naphthol per liter, referred to on pp. 514, 516 and 517 of the earlier paper is still maintained.

It is no longer necessary to add antimony since improved technique in solution purification appears to have overcome many of the difficulties previously experienced during electrolysis. Current efficiency averaging about 92 pct is maintained with a 72 hr stripping period.

## Melting and Casting Division

This operation was described in detail on pp. 519–526 of the earlier paper. The major change introduced during the intervening years has been the abandonment of coal firing and the use of oil in its place. No leaded zinc has been produced for some years.

## Metallurgical Data

The following tables refer to average figures for a four weekly period during the year ended June 30, 1948.

Feed solution was taken for analysis in June, 1947. During the year ended June 30, 1948 average cathode zinc output was 211.2 tons per day although it had risen to about 245 tons at the close of the year.

## Roasting Division

The data relevant to this division will be found in contemporary paper by J. A. B. Forster.

## Acknowledgment

The author wishes to express his appreciation to the Directors and Management of the Electrolytic Zinc Co. of Australasia Limited for permission to publish this paper. Also, his thanks are due to those who have helped in various ways in its preparation.

# Leaching Division

## *Table 1 . . . Pachuca Section*

| | |
|---|---|
| New calcine leached—tons | 11660 |
| Circulating load calcine and dross leached—tons | 3909 |
| Total calcine leached—tons | 15569 |
| Assay calcine leached | |
| Sulphate S Pct | 1.38 |
| Sulphide S Pct | 5.79 |
| Total Zn Pct | 56.6 |
| Sol. Zn Pct | 42.1 |
| Pb Pct | 1.0 |
| Fe Pct | 9.2 |
| Cu Pct | 0.18 |
| Cd Pct | 0.31 |
| Ag oz | 4.3 |
| Au oz | 0.017 |
| Spent electrolyte—acid grams per liter | 90.5 |
| Acid added to circuit—tons | 283 |
| Granular residue to flotation, pct of total calcine leached | 24.2 |
| Slime residue to flotation, pct of total calcine leached | 26.8 |

## *Table 4 . . . Copper Cadmium Cobalt and Chlorine Purification Sections*

| | |
|---|---|
| Zinc dust used—tons | 71 |
| —lb per ton cathode zinc | 26.7 |
| —pct of chemical equivalent of copper plus cadmium | 298 |

| | Solution Composition | |
|---|---|---|
| | Before Treatment | After Treatment |
| Copper—mg per liter | 112 | 0.1 |
| Cadmium—mg per liter | 176 | 1.8 |
| Copper cadmium precipitate—tons | | 192 |

| | Zn Pct | Pb Pct | Cu Pct | Cd Pct | Ag Oz. |
|---|---|---|---|---|---|
| Assay copper cadmium ppt | 33.6 | 0.6 | 6.7 | 10.85 | 2.3 |

| | |
|---|---|
| Cobalt removed—lb | 1801 |
| Beta naphthol used—lb per lb cobalt | 10.0 |
| Sodium nitrite—lb per lb cobalt | 6.9 |
| Caustic Soda—lb per lb cobalt | 3.17 |
| Lime—lb per lb cobalt | 14.2 |
| Chlorine removed—lb | 1090 |
| Silver loss—oz per lb chlorine removed | 0.99 |

## *Table 2 . . . Flotation Section*

| | |
|---|---|
| Granular residue treated—tons | 3696 |
| Assay sulphide sulphur—pct | 17.52 |
| Slime residue treated—tons | 4095 |
| Assay sulphide sulphur—pct | 8.02 |
| Combined concentrate—tons | 4041 |
| Slime tailing (or final residue)—tons | 3028 |
| Slime tailing pct of new calcine leached—pct | 26.0 |

| | Combined Concentrate | Slime Tailing |
|---|---|---|
| Sulphur sulphur pct | 22.5 | 1.99 |
| Total Zn pct | 49.4 | 22.3 |
| Pb pct | 0.8 | 4.0 |
| Cu pct | 0.21 | 0.14 |
| Cd pct | 0.70 | 0.13 |
| Ag oz | 10.2 | 6.5 |
| Au oz | 0.03 | 0.026 |

| Addition Agents | Pot. Xanthate | Eucalyptus | Cresylic Acid |
|---|---|---|---|
| Granular circuit—lb per ton | nil | 0.35 | nil |
| Slime circuit—lb per ton | 0.04 | 0.04 | 0.03* |

* Cresylic acid was not added throughout the year. This figure represents the normal addition when it was used.

## *Table 5 . . . Cobalt Oxide Section*

| | |
|---|---|
| Cobalt precipitate treated—tons | 42.5 |
| Cobalt content of crude precipitate—pct | 1.93 |
| Acid used—tons | 2.47 |

| | Ca Pct | $SiO_2$ Pct |
|---|---|---|
| Cobalt concentrate assay | 0.023 | 0.151 |

| | |
|---|---|
| Oil used in roasting—tons | 11 |
| Finishing temperature °C (approximate) | 750 |
| Output of oxide—tons | 1.0 |

| | Co Pct | Fe Pct | Zn Pct | Ca Pct | $SiO_2$ Pct |
|---|---|---|---|---|---|
| Cobalt oxide assay | 64.3 | 2.5 | 1.6 | 0.50 | 6.77* |

* This figure is abnormally high. It is usually about 2 pct.

## *Table 3 . . . Iron Purification Section*

| | |
|---|---|
| Solution treated—gal per day | 800,000 |

| | Solution Composition | |
|---|---|---|
| | Before Treatment | After Treatment |
| Sulphuric acid—g per liter | 1.95 | neutral |
| Total iron—mg per liter | 470 | 0.3 |
| Ferrous iron—mg per liter | 290 | |
| Silica—gms per liter | 1.65 | 0.112 |
| Arsenic—mg per liter | 2.65* | 0.2 |
| Antimony—mg per liter | 0.44* | 0.1* |
| Limestone used—tons† | | 600 |
| Iron precipitate—tons† | | 1200 |
| —Total zinc pct | | 7.0 |
| Water soluble zinc pct | | 3.5 |

* These figures are representative but are not necessarily yearly averages.

† The figures for limestone used and weight and composition of iron precipitate are typical but due to minor changes in procedure during the year do not depict the year's average work.

# Melting and Casting Division

## *Table 8 . . . Data on Melting*

| | |
|---|---|
| Cathode zinc melted—tons | 5877 |
| Proportion of scrap therein—pct | 2.02 |
| Zinc slabs cast—tons | 5658 |
| Dross produced—tons | 272 |
| Flue and baghouse dust (estimated) tons | 37 |
| Zinc content of dross—pct | 79.4 |
| Zinc recovery as slab zinc—pct | 96.27 |
| Oil consumed—pct of zinc fed | 2.29 |
| Ammonium chloride—lb per ton feed | 1.32 |

## *Table 9 . . . Analyses of Products*

| | High Grade Slab Zinc, Pct | Four Nines Cathode Zinc, Pct |
|---|---|---|
| Zinc | 99.9838 | 99.9918 |
| Lead | 0.0116 | 0.0048 |
| Copper | 0.0012 | 0.0011 |
| Cadmium | 0.0025 | 0.0023 |
| Iron | 0.0009 | <0.00001 |
| Arsenic | <0.00001 | <0.00001 |

# Electrolytic Division

## *Table 6 . . . Analysis of Feed Solution (June 1947)*

| | Grams Per Liter |
|---|---|
| Zinc | 111.9 |
| Manganese | 20.8 |
| Calcium | 0.44 |
| Magnesium | 1.7 |
| Sodium | 3.7 |
| Potassium | 1.36 |
| Sulphate | 219.4 |
| | Mg Per Liter |
| Cobalt | 9.4 |
| Copper | 0.11 |
| Cadmium | 1.6 |
| Silica | 102 |
| Total Chlorine | 139 |
| Chloride chlorine | 99 |
| Chlorate chlorine | Nil |
| Perchlorate chlorine | 40 |
| Fluorine | 32 |
| Arsenic | <0.1 |
| Antimony | 0.09 |

| | Mg Per Liter |
|---|---|
| Total Nitrogen | 142 |
| $NH_4$ nitrogen | 138 |
| Nitrite nitrogen | 3 |
| Nitrate nitrogen | Possible trace |
| Phosphate | Trace |
| Aluminum | 0.44 |
| Lead | 0.07 |
| Bismuth | 0.001 |
| Nickel | 0.2 |
| Selenium | Nil |
| Tellurium | Nil |
| Tin | 0.065 |
| Silver | 0.35 |
| Iron (total) | 1.2 |
| Iron (after filtration) | <0.1 |
| Solids in suspension | 74 |
| Specific Gravity | 1.344 |

## *Table 7 . . . Data on Electrolysis*

| | |
|---|---|
| Output of cathode zinc—tons | 5917 |
| Anode current density—amp per sq ft | |
| At 12000 amp | 28.3 |
| At 18000 amp | 32.1 |
| Cathode current density—amp per sq ft | |
| At 12000 amp | 26.2 |
| At 18000 amp | 29.4 |
| Voltage per unit at 12000 amp | 502 |
| Voltage per unit at 18000 amp | 507 |
| Current efficiency—pct | 92.0 |
| Zinc deposited—lb per dc hp day | 12.59 |
| Zinc deposited—lb per ac hp day | 11.47 |
| Glue—lb per ton cathode zinc | 0.84 |
| Beta naphthol—lb per ton cathode zinc | 0.33 |

# The Hardenability Effect of Molybdenum

J. M. HODGE,* J. L. GIOVE,* Members AIME, and R. G. STORM*

## Introduction

THE hardenability effect of molybdenum has been evaluated by a number of investigators, including one of the present authors.[1,2,3,4,6] Considerable discrepancy exists, however, among the results of these various investigators, and two of them, Brophy[3] and Kramer,[4] have indicated that the apparent hardenability effect of molybdenum would vary, depending upon the other alloying elements in the steels being considered. The results of previous, unpublished work conducted at the Duquesne Works Laboratory of the Carnegie-Illinois Steel Corporation also have indicated significant differences in the hardenability effect of molybdenum in nickel and in chromium steels.

The present investigation was undertaken in an effort to establish the mechanism governing this difference in the hardenability effect of molybdenum. This work involved both end-quench hardenability and isothermal transformation tests on two series of steels of varying molybdenum content. One steel contained 3 pct nickel and the other 1 pct chromium. It was hoped that such studies would shed further light on the mechanism of this behavior.

## Materials and Experimental Work

### MATERIALS

The chemical compositions of the steels used in this investigation are shown in Table 1. These steels were furnished by Battelle Memorial Institute in the form of 100-lb induction furnace ingots. The top half of each ingot was forged to 1⅜-in. square billets and then rolled to 1-in. round bar stock for isothermal transformation studies. The bottom half of each ingot was forged into approximately 1¼-in. rounds for end quench tests. All of the steels were normalized from 1650°F and tempered at 1100°F before machining to end quench or isothermal samples.

*Table 1 . . . Results of Ladle Chemical Analyses—Per Cent*

| C | Mn | P | S | Si | Cr | Ni | Mo | Al |
|---|---|---|---|---|---|---|---|---|
| 3 Pct Nickel Steels | | | | | | | | |
| 0.41 | 0.70 | 0.019 | 0.030 | 0.28 | | 3.02 | 0.0 | 0.020 |
| 0.39 | 0.68 | 0.021 | 0.028 | 0.27 | | 3.01 | 0.08 | 0.025 |
| 0.40 | 0.69 | 0.018 | 0.028 | 0.32 | | 2.99 | 0.18 | 0.025 |
| 0.40 | 0.71 | 0.019 | 0.028 | 0.26 | | 3.00 | 0.32 | 0.025 |
| 0.95 Pct Chromium Steels | | | | | | | | |
| 0.41 | 0.68 | 0.018 | 0.027 | 0.27 | 0.95 | 0.05 | 0.0 | 0.025 |
| 0.41 | 0.69 | 0.018 | 0.028 | 0.21 | 0.95 | 0.05 | 0.08 | 0.025 |
| 0.42 | 0.69 | 0.018 | 0.028 | 0.23 | 0.94 | 0.05 | 0.18 | 0.025 |
| 0.42 | 0.65 | 0.018 | 0.028 | 0.20 | 0.94 | 0.05 | 0.32 | 0.025 |

Note: For calculating ideal diameters, these analyses were corrected to 0.40 pct C, 0.70 pct Mn, and 0.25 pct Si.

### END-QUENCH TESTS

Standard 1-in. diam end-quench tests were made on each of the steels. The test bars were austenitized at 1600°F for 30 min., quenched in a standard Jominy jig, and hardness surveys were made in all tests. The 95 pct martensite point was determined from hardness values[5] and checked by metallographic examination. The Jominy distance values for 95 pct martensite were converted to hardenability values in terms of ideal diameter ($D_I$), using a revised curve for the relationship between Jominy distance and ideal diameter. This curve was based on the cooling time from the $A_1$ to the bainite nose temperatures rather than on the usual criterion of half-temperature time. The cooling rates as determined by Russell and Williamson[9] were used as a basis for this relationship. The derivation of this curve is described in detail in the appendix.

### ISOTHERMAL TRANSFORMATION STUDIES

Samples for the isothermal transformation studies were quarter sectors of 1/16-in. thick slices from the 1-in. round bars. All samples were austenitized for a total time of 15 min., transferred rapidly to a lead bath for isothermal transformation, and brine quenched from the lead bath. A time of 3 sec was allowed for the sample to come to the temperature of the lead bath, and this time was not included in the isothermal transformation times.

Each sample was examined metallographically at a magnification of 100 diam. The per cent transformation was estimated by comparison with standard micrographs, and the values were plotted against time on log/log coordinate paper. At least 4 and as many as 10 points were plotted for each steel. A line was drawn through the points for each steel, and the times for 5 pct transformation were obtained from the plot for each steel.

Isothermal transformation diagrams in terms of 5 pct total transformation, covering the temperature range of 800 to 1200°F, were determined in this manner for an austenitizing temperature of 1600°F. The times for 5 pct transformation at the bainite nose for austenitizing temperatures of 1800 and 2000°F were also determined in the same manner.

These times for 5 pct total transfor-

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TP 2520 E. Discussion of this paper (2 copies) may be sent to *Transactions* AIME before Dec. 15, 1949. Manuscript received November 1, 1948.

* Carnegie-Illinois Steel Corporation, Pittsburgh, Pa.

References are at the end of the paper.

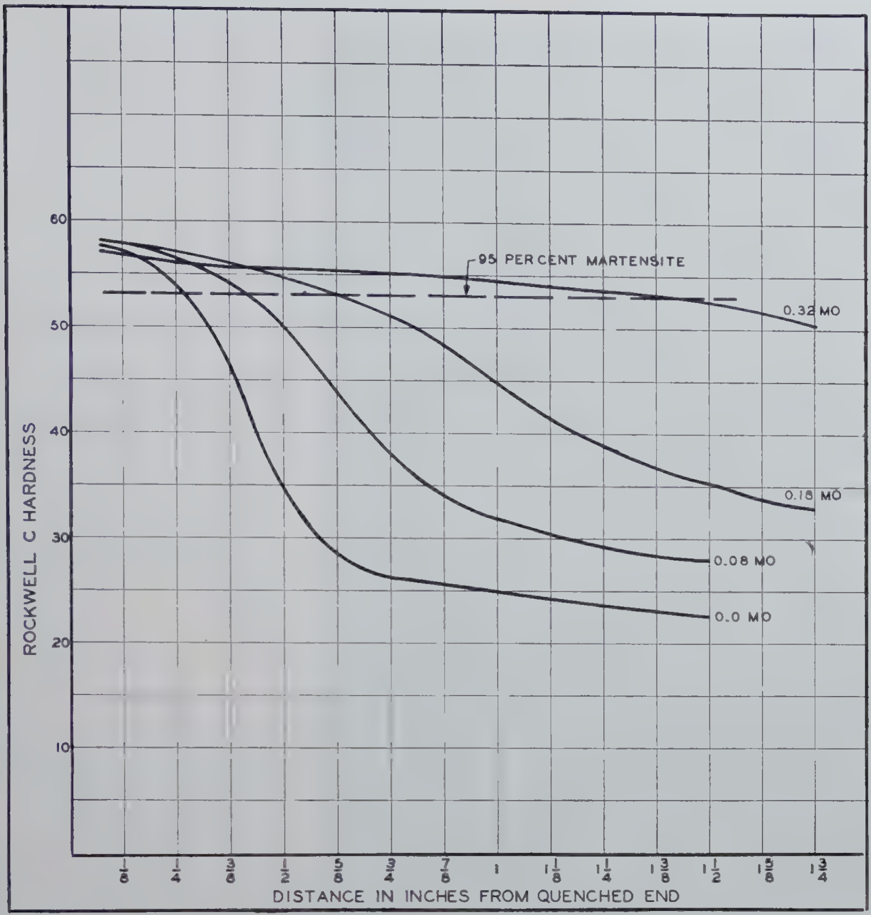


FIG 1—End quench hardenability curves for a series of 3 pct nickel steels.

mation at the bainite nose were converted to hardenability values in terms of ideal diameter by multiplying them by a factor of 1.5 and correlating the results with the cooling times from the $A_1$ to the bainite nose temperature in an ideal quench. This method is described in detail in the appendix.

## Results and Discussion

The results of the hardness surveys on the end-quenched samples, austenitized at 1600°F, are shown in Fig 1 and 2. The 95 pct martensite points, determined microscopically, are also indicated on these curves. The location of this microstructure corresponds in general with the hardness value for 95 pct martensite as reported in Ref. 5. The hardenability factors for molybdenum, determined by dividing the ideal diameters of the steels containing molybdenum by the ideal diameters of those containing no molybdenum, are shown in Fig 3. It is evident that the hardenability effect of molybdenum is much more pronounced in the nickel than in the chromium steels. It is, perhaps, significant that the hardenability factors for molybdenum in the chromium steel correspond approximately to those originally determined by Grossmann,[1] which are also shown.

The microstructures at the 95 pct martensite point on the end-quench test samples of each series containing 0.18 pct molybdenum are shown in Fig 4 and 5. The nonmartensitic products are predominantly bainitic in both steels. Some acicular ferrite is to be noted, however, and the nickel steel shows somewhat more of this apparently ferritic constituent.

The isothermal transformation studies were undertaken principally to determine if the hardenability differences noted in the results of end-quench tests reflected actual differences in the rate of transformation to bainite, or if they were associated with incubation effects or differences in nucleation which occurred during continuous cooling. The results of the isothermal transformation studies from samples austenitized at 1600°F are summarized by isothermal transformation diagrams in Fig 6 and 7. It is apparent from the diagrams that the transformation rates in both the pearlitic and bainitic regions have been decreased in both types of steel by the addition of molybdenum. There are also large differences in the

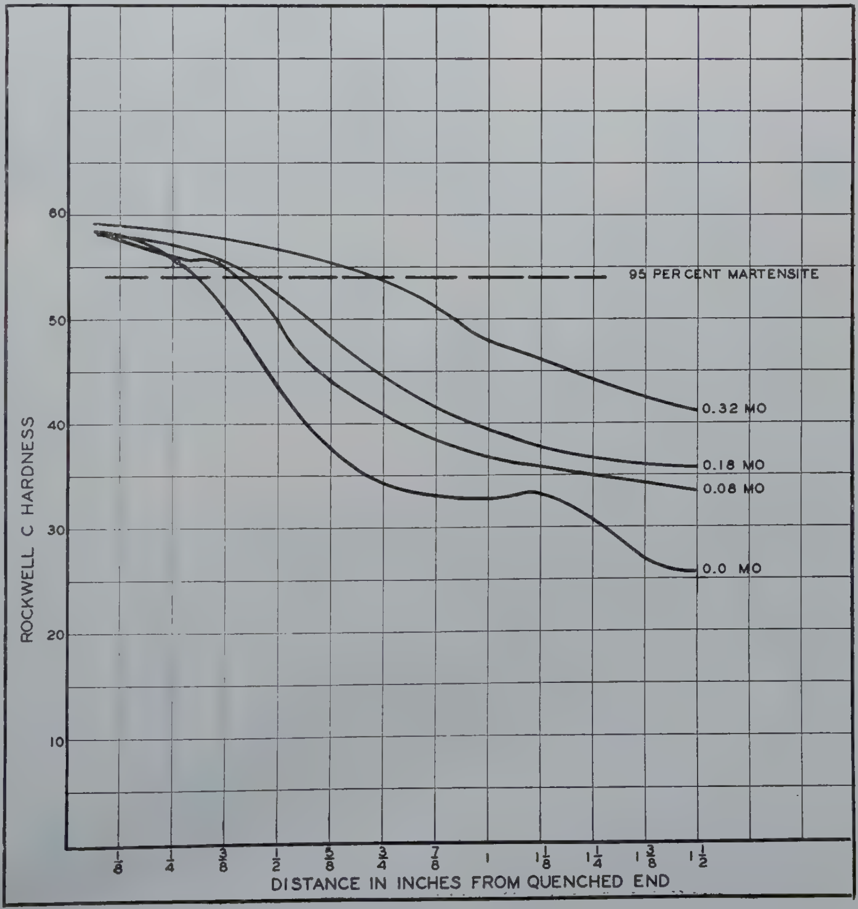


FIG 2—End quench hardenability curves for a series of 0.95 pct chromium steels.

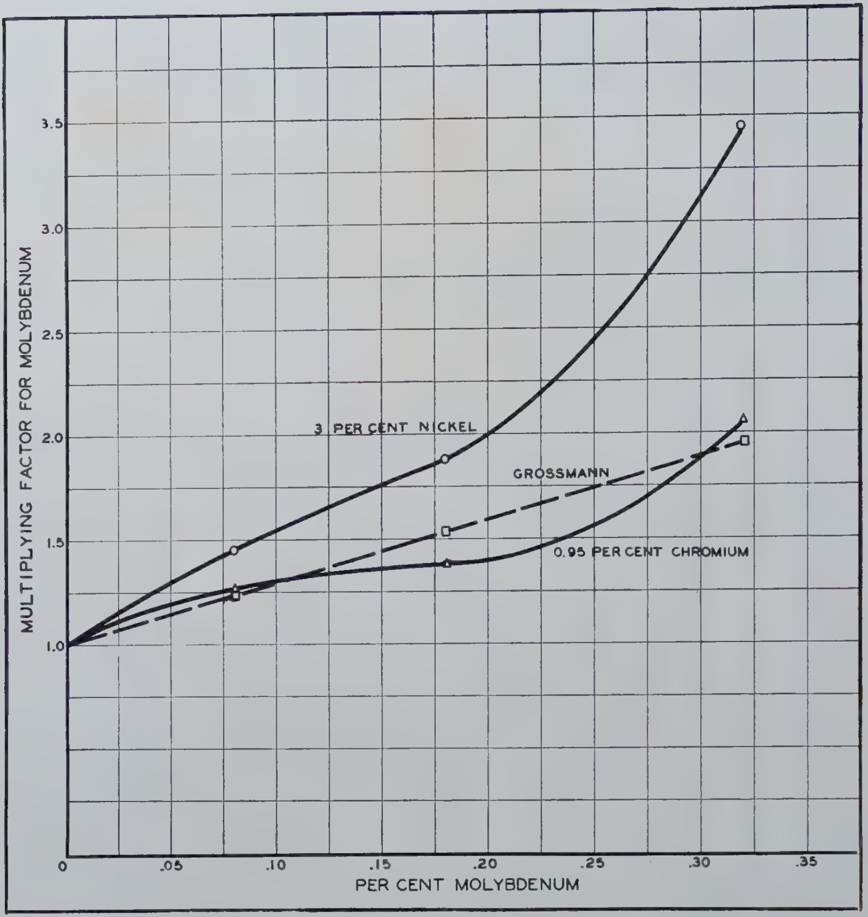


**FIG 3—The hardenability effect of molybdenum in 3 pct nickel and 0.95 pct chromium steels. End quench tests.**

*Table 2 . . . End Quench Test Results and Corresponding Hardenability Values*

Jominy Bars

| 3 Pct Nickel Steels | | | | 0.95 Pct Chromium Steels | | | |
|---|---|---|---|---|---|---|---|
| Pct Mo | $J_D$ (Inches) | $D_I$ (Inches) | $M_F$ | Pct Mo | $J_D$ (Inches) | $D_I$ (Inches) | $M_F$ |
| 0.0 | 0.27 | 2.05 | 1.00 | 0.0 | 0.31 | 2.19 | 1.00 |
| 0.08 | 0.40 | 2.97 | 1.45 | 0.08 | 0.388 | 2.76 | 1.26 |
| 0.18 | 0.625 | 3.87 | 1.88 | 0.18 | 0.45 | 3.03 | 1.38 |
| 0.32 | 1.41 | 7.06 | 3.44 | 0.32 | 0.733 | 4.51 | 2.06 |

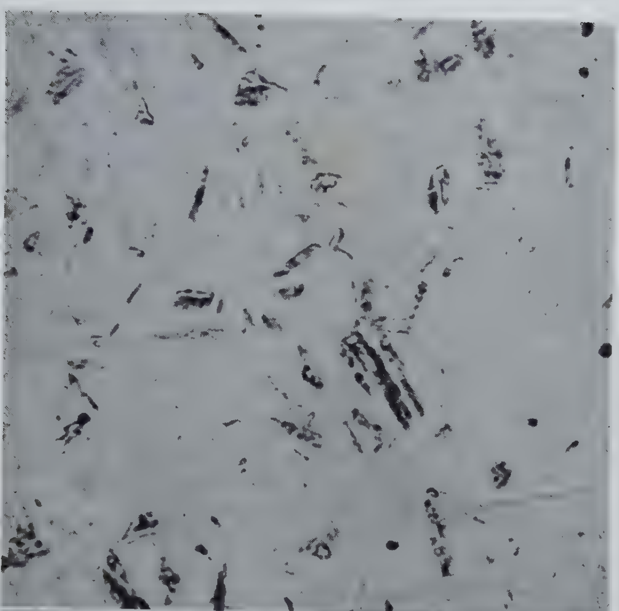
Note: $J_D$ = Jominy bar distance to 95 pct martensite
$D_I$ = Ideal diameter
$M_F$ = Multiplying factor

magnitudes of these effects in the two types of steel. The molybdenum was much more effective in decreasing the transformation rates, in the temperature range 1000 to 1200°F, in the nickel than in the chromium steels.

As will be evident, this effect on the rates of transformation at the higher temperatures is not particularly pertinent to the present investigation, which is concerned with 95 pct martensite hardenability, the nonmartensitic products being predominantly bainitic. However, the large differences in the rates of transformation in the pearlitic range in the two types of steel would be very important if one were concerned with transformation to pearlitic microstructures.

There are also evident differences in the effect of molybdenum on the transformation rates at the bainite nose in the two types of steel. On converting these transformation time values to hardenability values, by the methods mentioned above and described in detail in the appendix, it is evident that these differences in the hardenability effects, as expressed by the multiplying factors, are identical with those observed in the end-quench tests. The hardenability values for the end-quench and the isothermal transformation tests are given in Tables 2 and 3, respectively. It is apparent that, although the ideal diameters determined from the results of the end-quench tests are larger than those determined from the isothermal studies from an austenitizing temperature of 1600°F, the multiplying factors for molybdenum, calculated from the results of both tests, are substantially the same. These multiplying factors expressing the hardenability effect of molybdenum in both the end-quench and isothermal transformation tests are plotted as a function of molybdenum content in Fig 8. Thus the hardenability effect of molybdenum and the differences in its effect in the two types of steel, as shown by the results of end-quench tests, are seen to be fully accounted for by the effect of molybdenum on the isothermal transformation rate to bainite.

Micrographs illustrating the appearance of the transformation products which formed at the nose temperature



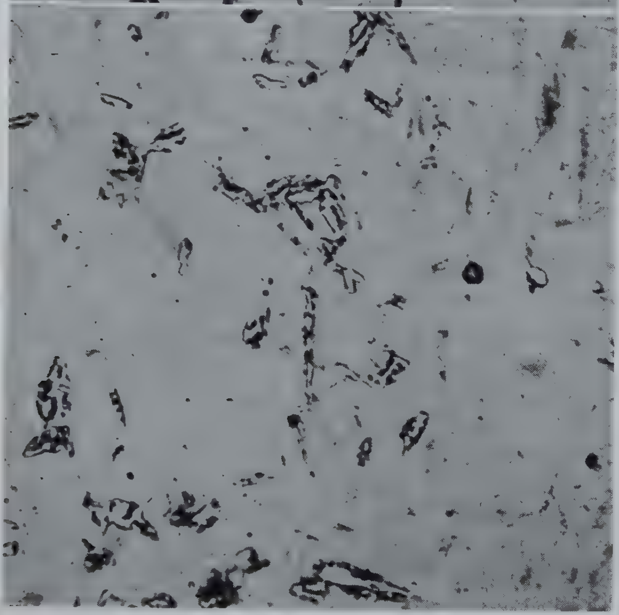


FIG 4—(Above) Microstructure of the end-quench bar at approximately 95 pct martensite in the 3 pct nickel, 0.18 pct molybdenum steel. Picral-zephiran chloride etch. × 1000.

FIG 5—(Below) Microstructure of the end-quench bar at approximately 95 pct martensite in the 0.95 pct chromium, 0.18 pct molybdenum steel. Picral-zephiran chloride etch. × 1000.

after about 5 pct transformation are shown in Fig 9 and 10. These products are similar in appearance to those observed at the 95 pct martensite point in the end-quench test samples. As would be expected, however, the transformation during the continuous cooling of the end-quench test samples evidently occurred at a somewhat lower average temperature than the isothermal nose temperature.

One plausible explanation for this difference in the hardenability effect of molybdenum in nickel and in chromium steels might be that it reflects differences in the rate of carbide solution in the two steels, at a given austenitizing temperature. In order to check this hypothesis, isothermal transformation studies were made at the bainite nose temperature, using austenitizing temperatures of 1800 and 2000°F. The results of these studies are superimposed on the isothermal transformation diagrams of Fig 6 and 7, and the corresponding hardenability values as a function of austenitizing temperature are shown in Fig 11 and in Table 3. The multiplying factors expressing the hardenability effects of molybdenum in samples austenitized at these higher temperatures are superimposed on Fig 8 along with corresponding factors for 1600°F austenitization. It can be seen that, although the transformation rates to bainite are markedly decreased by increasing the austenitizing temperature, the hardenability effect of molybdenum and the differences in its effect on the two series of steels, remains unchanged with changes in the austenitizing conditions within the temperature range 1600 to 2000°F.

The probability appears remote that the rate of carbide solution with in-

## *Table 3 . . . Isothermal Test Results and Corresponding Hardenability Values*

Isothermal Tests

| Pct Mo | Bainite Nose Times (Seconds) | $D_I$ (Inches) | $M_F$ | Pct Mo | Bainite Nose Times (Seconds) | $D_I$ (Inches) | $M_F$ |
|---|---|---|---|---|---|---|---|
| 1600°F | | | | | | | |
| 0.0 | 2.33 | 1.73 | 1.00 | 0.0 | 3.42 | 1.68 | 1.00 |
| 0.08 | 4.06 | 2.38 | 1.38 | 0.08 | 4.60 | 2.04 | 1.21 |
| 0.18 | 8.84 | 3.25 | 1.88 | 0.18 | 7.60 | 2.43 | 1.45 |
| 0.32 | 26.8 | 5.97 | 3.45 | 0.32 | 11.8 | 3.43 | 2.04 |
| 1800°F | | | | | | | |
| 0.0 | 5.17 | 2.48 | 1.00 | 0.0 | 7.0 | 2.47 | 1.00 |
| 0.08 | 9.8 | 3.54 | 1.43 | 0.08 | 10.0 | 3.07 | 1.24 |
| 0.18 | 18.6 | 4.56 | 1.84 | 0.18 | 16.0 | 3.76 | 1.52 |
| 0.32 | 55 | 8.30 | 3.35 | 0.32 | 24 | 4.83 | 1.96 |
| 2000°F | | | | | | | |
| 0.0 | 13.7 | 4.19 | 1.00 | 0.0 | 13.4 | 3.36 | 1.00 |
| 0.08 | 23.6 | 5.78 | 1.38 | 0.08 | 21.4 | 4.41 | 1.31 |
| 0.18 | 48 | 7.60 | 1.81 | 0.18 | 29.6 | 5.02 | 1.49 |
| 0.32 | 132 | 13.3 | 3.17 | 0.32 | 52 | 7.00 | 2.08 |

Note: $D_I$ = Ideal diameter
$M_F$ = Multiplying factor

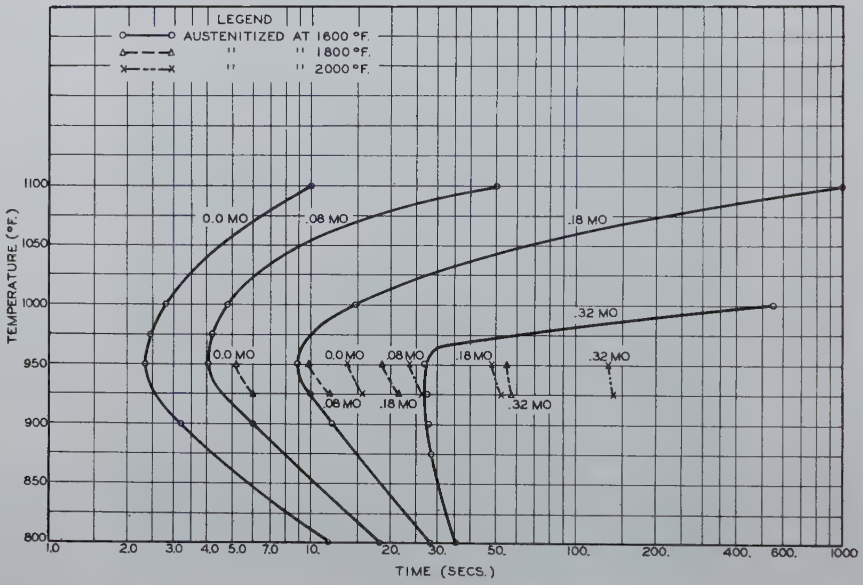


FIG 6—Isothermal transformation diagram for 5 pct total transformation in 3 pct nickel-molybdenum steels.

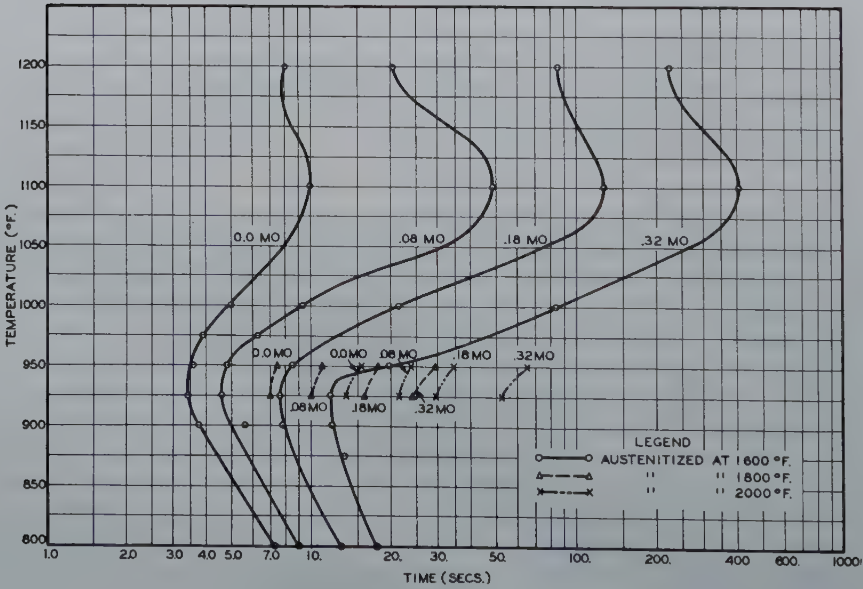


FIG 7—Isothermal transformation diagram for 5 pct total transformation in 0.95 pct chromium-molybdenum steels.

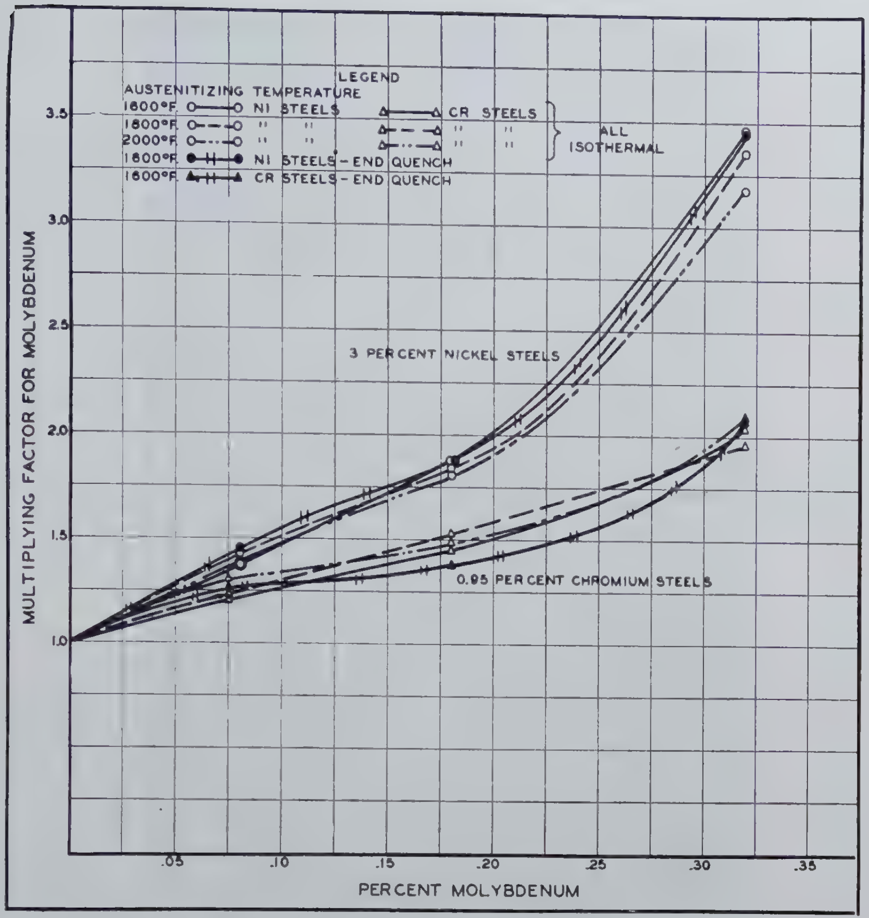


FIG 8—The hardenability effect of molybdenum as determined by end quench and isothermal transformation tests.

creasing austenitizing temperatures has caused these large increases in hardenability, because no undissolved carbides were observed in any of the steels after austenitizing at 1600°F. Furthermore, the increase is as marked in the nickel steel without molybdenum as it is in the chromium steel with 0.32 pct molybdenum. The increase in hardenability correlates roughly with the increase in grain size which accompanied the increased austenitizing temperature. This increase in hardenability, however, seems rather large to be ascribed altogether to the increased grain size, particularly as it is based on transformation rates in the bainite region.

## Conclusions

1. The hardenability effect of molybdenum, based on end-quench tests of two series of steels, one with a base composition of 0.40 pct carbon and 3 pct nickel and the other with a base composition of 0.40 pct carbon and 1 pct chromium was more pronounced in the nickel steels; 0.32 pct molybdenum was about twice as effective in the presence of 3 pct nickel as in the presence of 1 pct chromium.

2. The hardenability effect of molybdenum in both steels, and the difference in its effect in the presence of nickel and chromium are quantitative reflections of its effect on the rate of transformation at the bainite nose temperature.

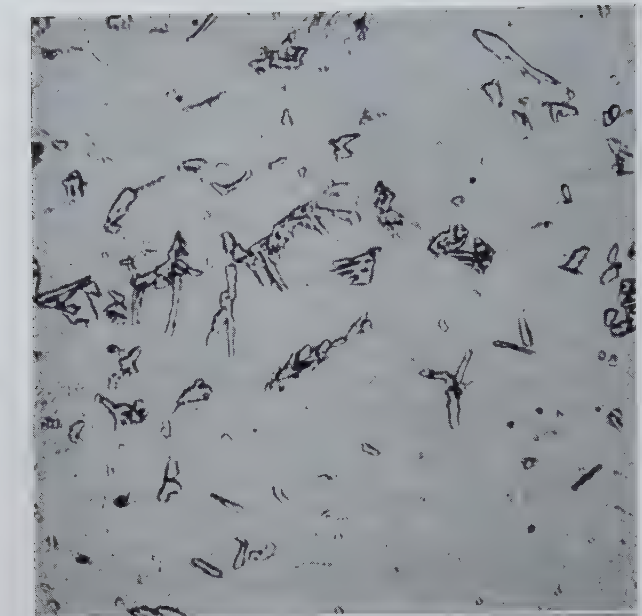
3. The hardenability effect of molybdenum in the presence of either nickel or chromium is unaffected by changes in austenitizing temperature over the temperature range of 1600 to 2000°F.

4. The explanation of the difference in the effect of molybdenum on transformation rates to bainite in the presence of nickel or chromium was not apparent, but it did not seem to reflect differences in the rate of carbide solution in the two types of steels.

## Appendix

### CALCULATION OF HARDENABILITY VALUES FROM END-QUENCH AND ISOTHERMAL DATA

As mentioned in the body of this report, the hardenability values, as derived from the results of either the end-quench or isothermal transformation studies, are based on the cooling time from the $A_1$ to the bainite nose temperatures. This criterion was chosen because it permitted the isothermal transformation times at the bainite



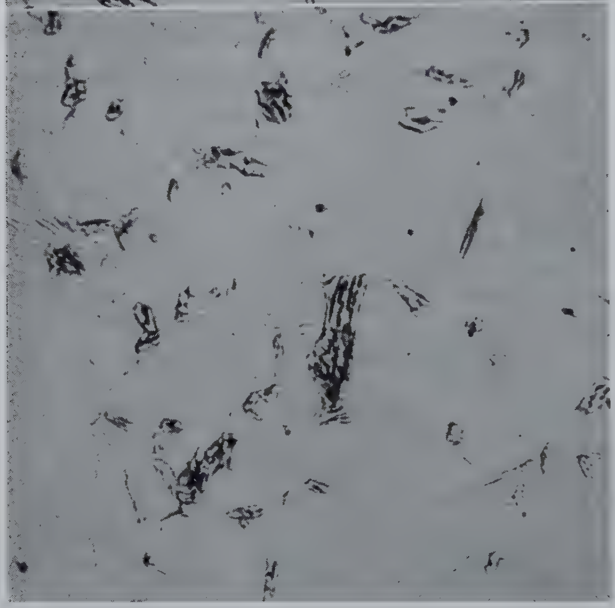


**FIG 9—(Above) Microstructure of isothermal sample at the bainite nose temperature after about 5 pct transformation in the 3 pct nickel, 0.18 pct molybdenum steel. Picral-zephiran chloride etch. × 1000.**

**FIG 10—(Below) Microstructure of isothermal sample at the bainite nose temperature after about 5 pct transformation in the 0.95 pct chromium, 0.18 pct molybdenum steel. Picral-zephiran chloride etch. × 1000.**

nose to be converted to hardenability values by the method developed by Grange and Kiefer.[7] For consistency, therefore, the same criterion was used in evaluating the end-quench test results.

The correlation curves between Jominy distance and ideal diameter for the two series of steels, based on this criterion, are shown in Fig 12. The cooling time from $A_1$ to the bainite nose temperatures, on which the ideal diameter values of these curves are based, were determined from the cooling rates along the end-quench bar which were recently published by Russell and Williamson.[9] These cooling rates, plotted in terms of fractional temperature as a function of time, are reproduced in Fig 13.

In order to convert the cooling times from the $A_1$ to the bainite nose temperatures to ideal diameter values, such cooling times for a series of cylinder sizes, assuming an infinite quench and diffusivity of 0.0099 sq. in. per sec were calculated from Russell's tables.[8] From these times, plots correlating cooling time and ideal diameter were prepared for austenitizing temperatures of 1600, 1800, and 2000°F. These plots are shown in Fig 14, 15, and 16.

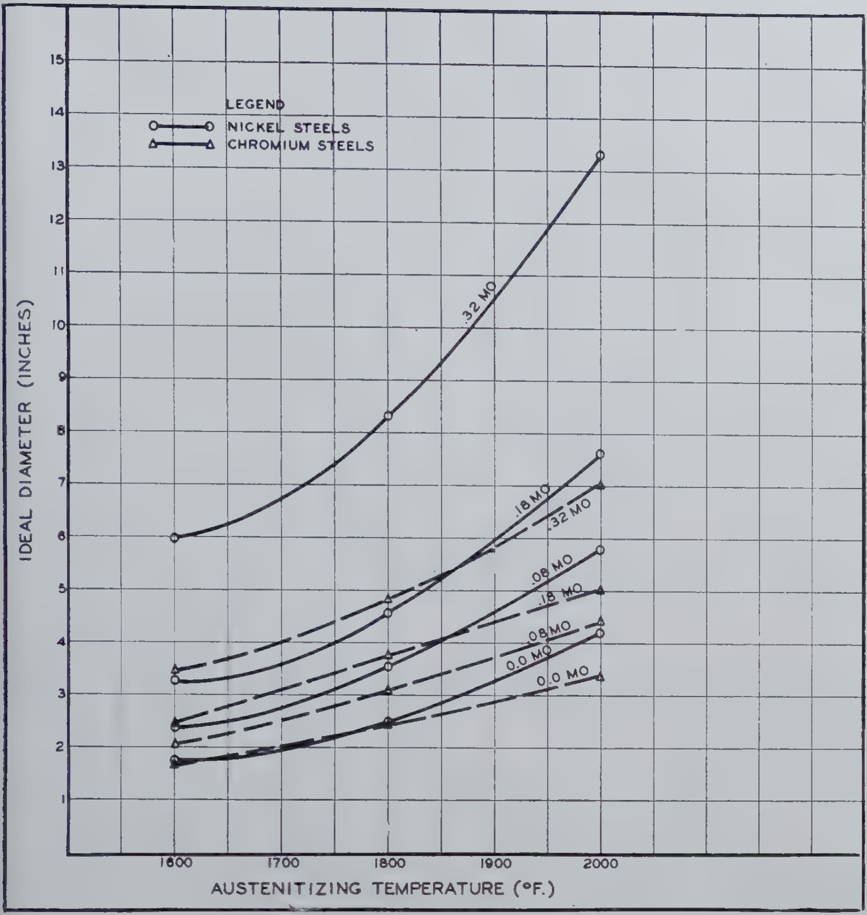


FIG 11—Hardenability as a function of austenitizing temperature in nickel-molybdenum and chromium-molybdenum steels.

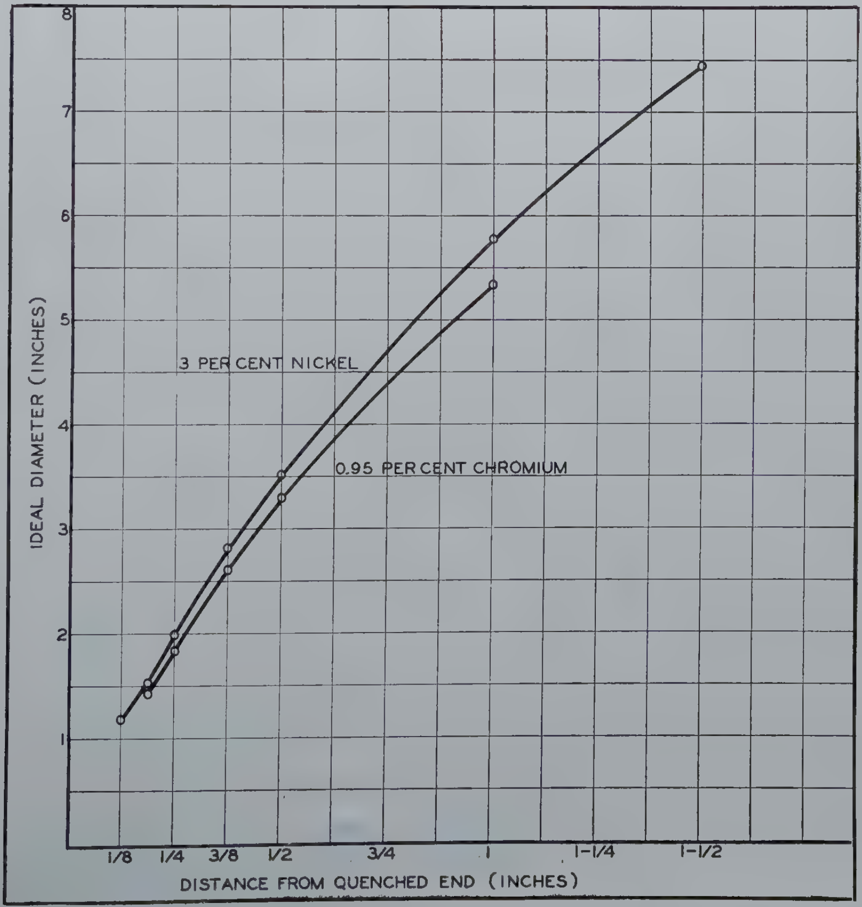


FIG 12—Relationship between Jominy distance and hardenability based on cooling time from $A_1$ to the bainite nose temperature.

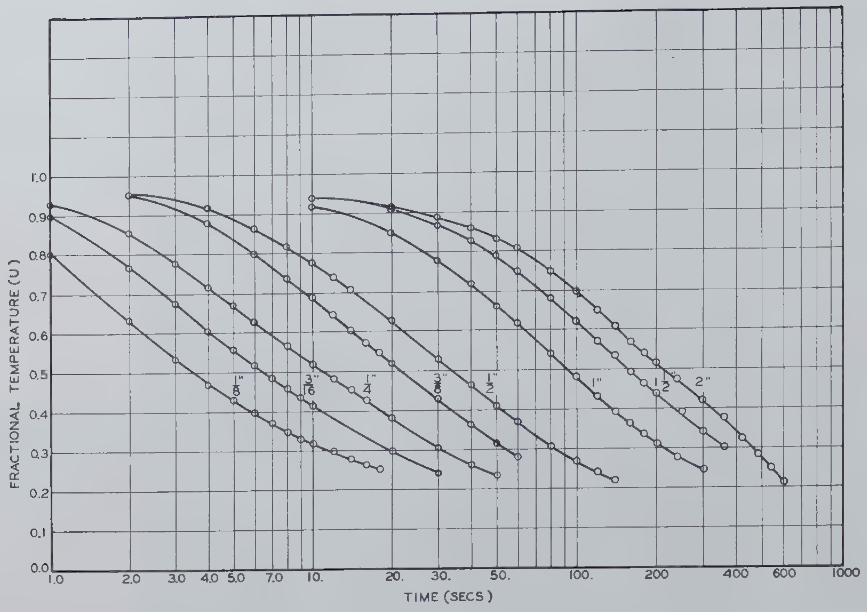


FIG 13—Cooling rates at different locations along an end quench bar quenched from approximately 1600°F. (Russell and Williamson.)

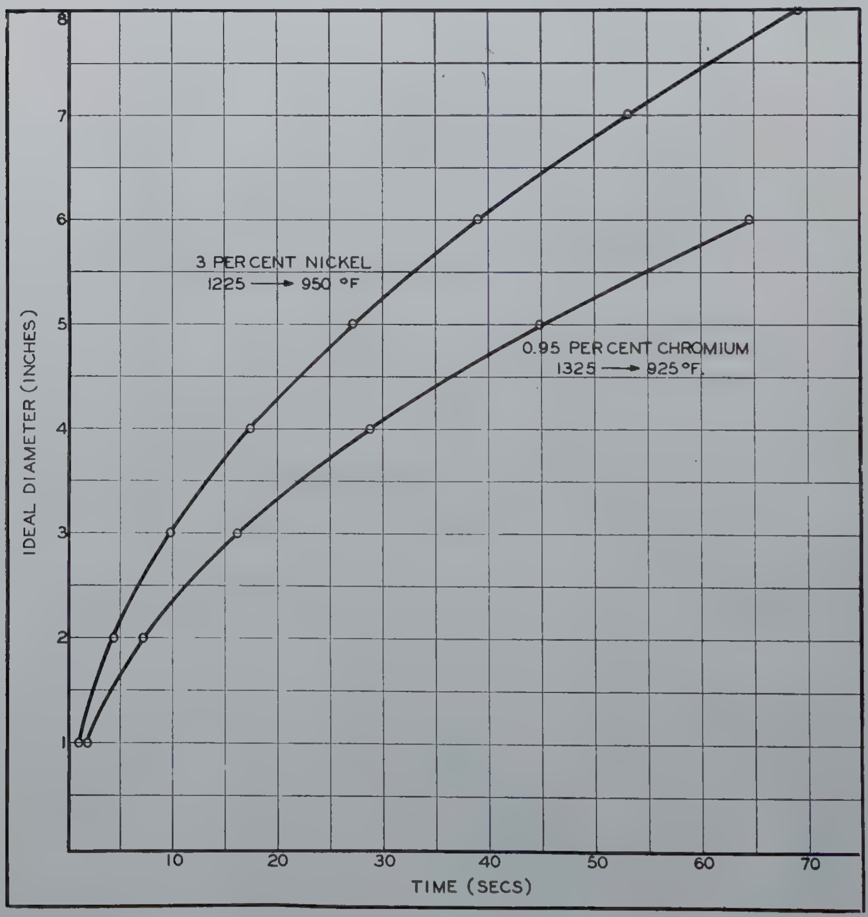


FIG 14—Relationship between ideal diameter and time to cool from the $A_1$ to the bainite nose temperatures. Austenitized at 1600°F.

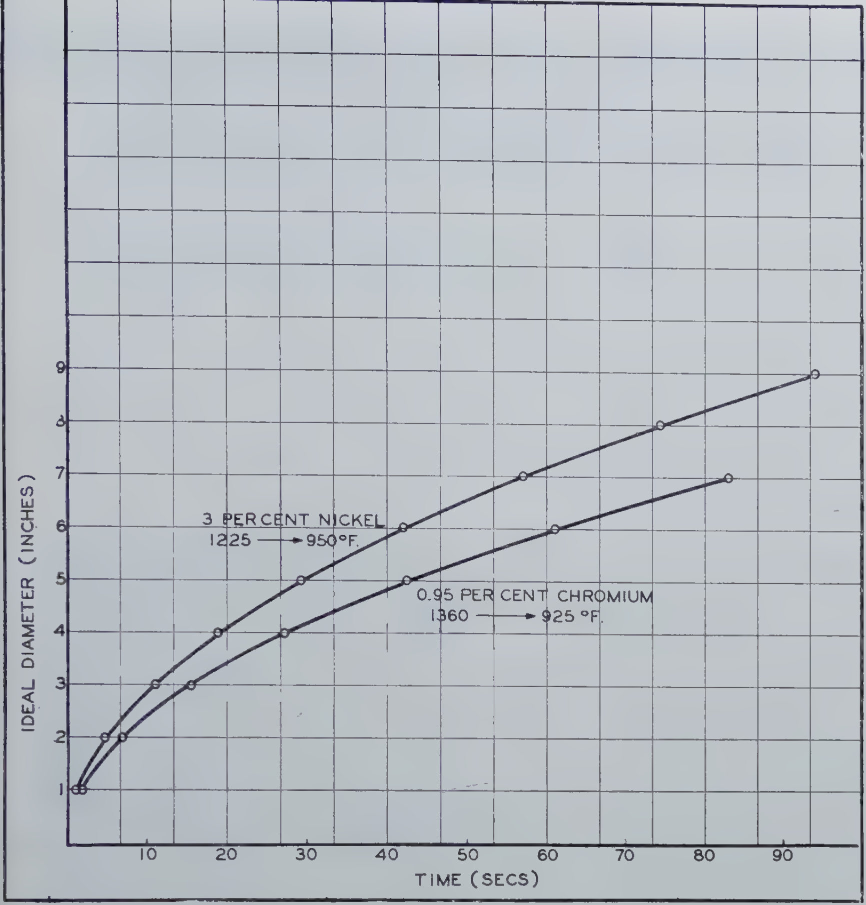


FIG 15—Relationship between ideal diameter and time to cool from the $A_1$ to the bainite nose temperatures. Austenitized at 1800°F.

The relationships between the distance from the quenched end of the Jominy bar and the ideal diameter, as shown in Fig 12, are therefore based on the cooling times as determined from Fig 13, and the relationship between cooling time and ideal diameter as shown in Fig 14. The hardenability values corresponding to the isothermal transformation times at the bainite nose were likewise determined from Fig 14, 15, and 16. These isothermal transformation times were multiplied by a factor of 1.5 before making this conversion. This factor of 1.5 represents the average relationship between the continuous cooling time from the $A_1$ to the nose temperatures and isothermal transformation time at the nose temperature, as determined by Grange and Kiefer.[7]

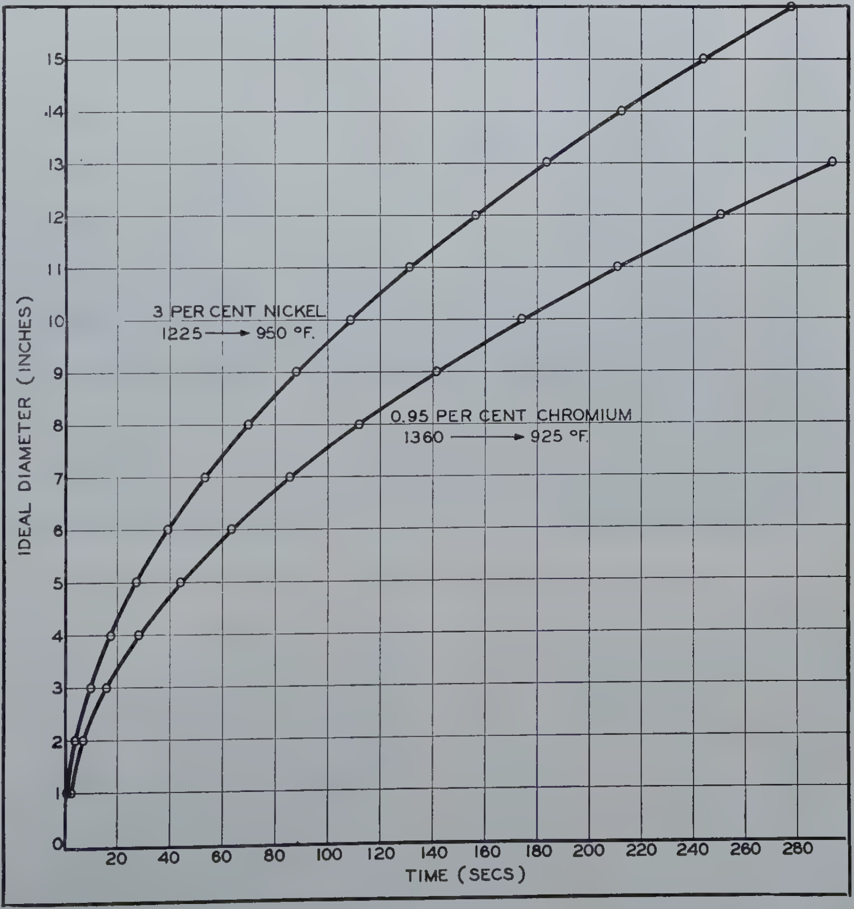


FIG 16—Relationship between ideal diameter and time to cool from the $A_1$ to the bainite nose temperatures. Austenitized at 2000°F.

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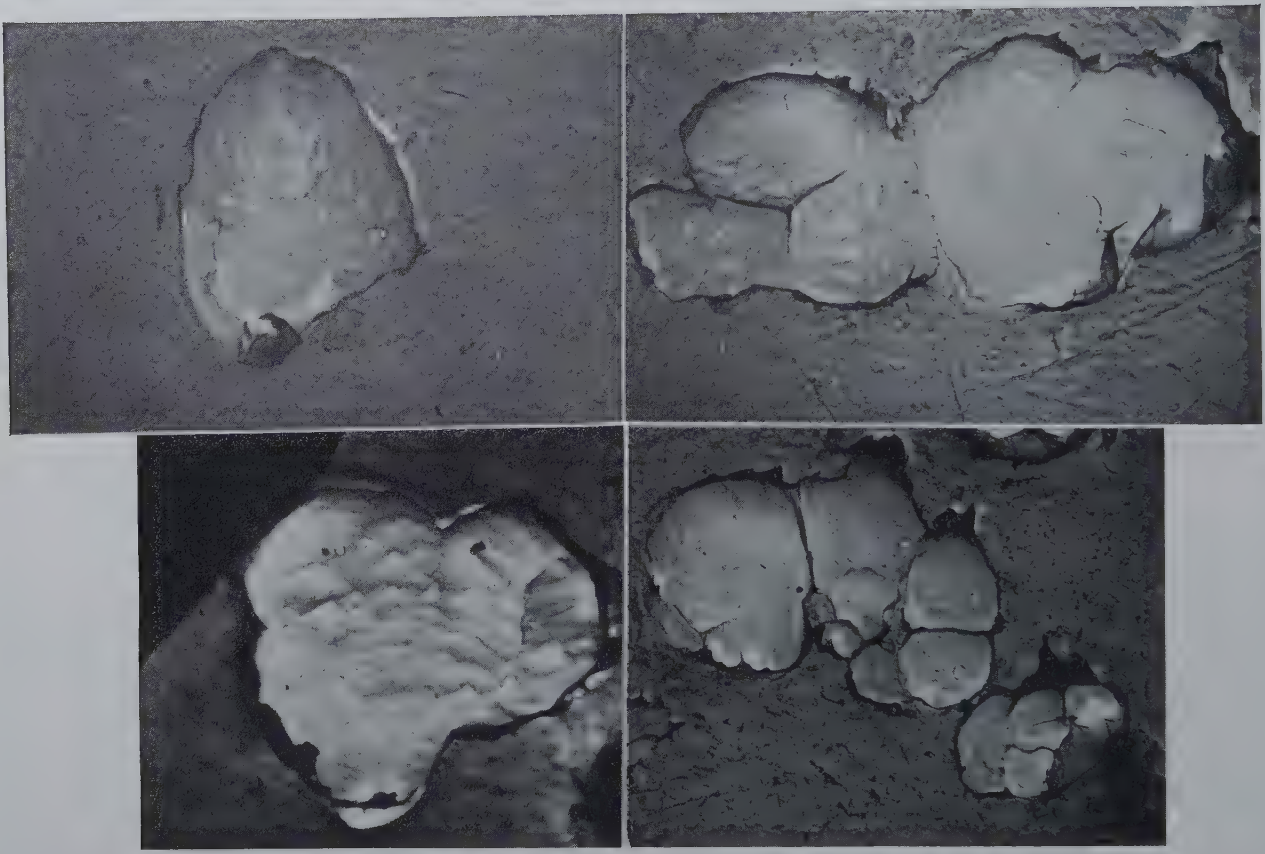
# A Method of Examination of Sections of Fine Metal Powder Particles with the Electron Microscope

LAURENCE DELISLE*



FIG—1 Tungsten powder particles × 10,000. Reduced approximately one fourth in reproduction.

## Introduction

THE aim of this paper is the description of a technique to be applied to the study of sections of metal powder particles, less than 20 microns in diam, with the electron microscope, by the replica method, using for replica a material such as formvar or parlodion.

This work originated with the study of particles of tungsten powders. Such particles were too small to be examined in sufficient detail with the light microscope. On the other hand, examination with the electron microscope of the powders dispersed in the supporting film was not found satisfactory because: 1. It did not permit differentiating between single particles and aggregates. 2. It did not show the true outlines of the particles but only the projection of a whole surface. 3. No details appeared. For that reason it was attempted to make replicas of sections of the particles imbedded in a mounting material suitable for polishing and etching. The method proved satisfactory for the examination of tungsten powder and was then extended to carbonyl nickel and carbonyl iron powders.

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## Procedure

Several mounting materials commonly used in ordinary metallography were investigated. The problem consisted in finding a mounting material

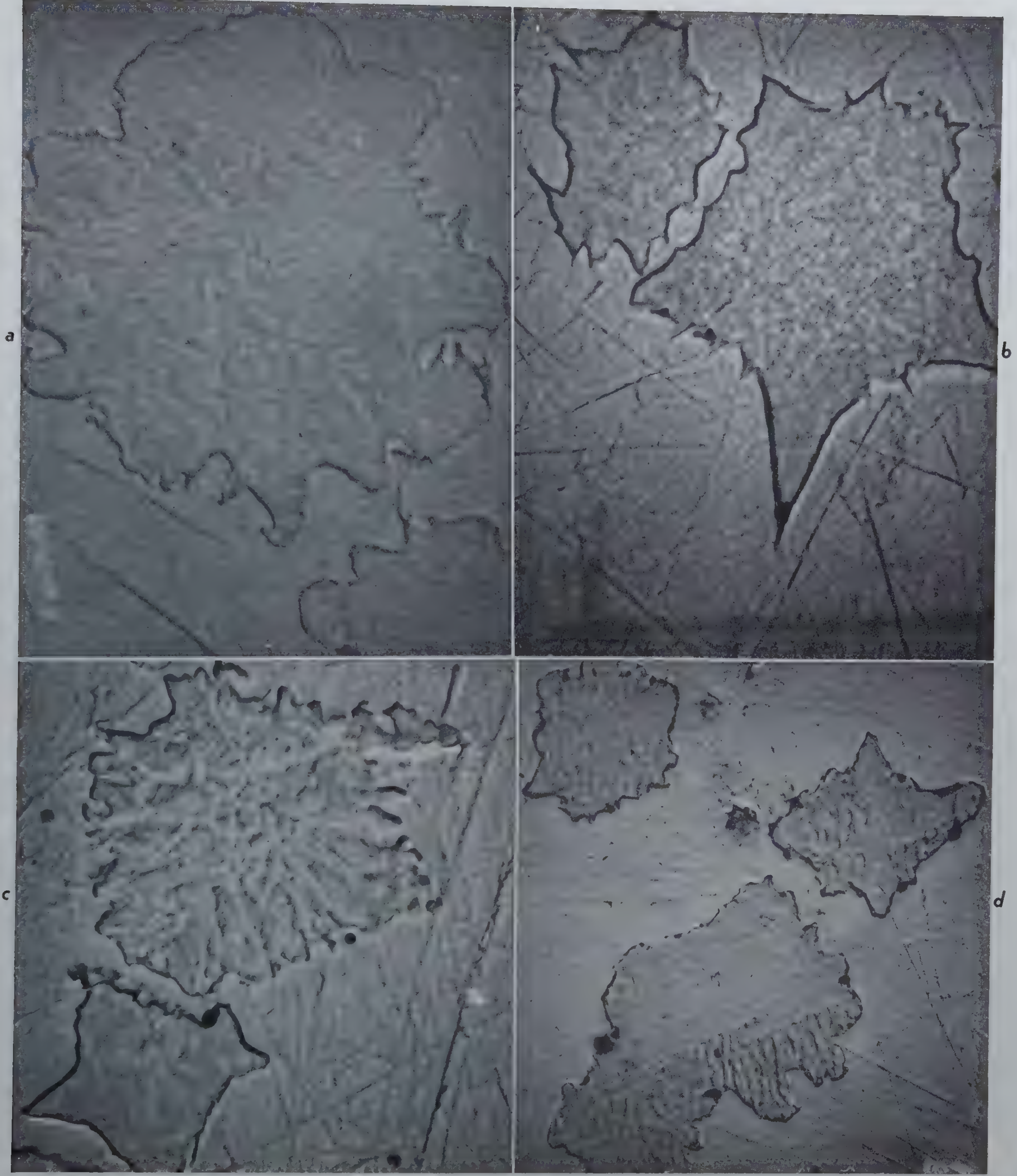

FIG 2—Particles of carbonyl nickel powder. *a*, *b*, *c*, × 10,000. *d*, × 5,000. Slightly reduced in reproduction.

that would (1) wet the metal particles, (2) be of proper hardness to give, after polishing, a fairly smooth surface from which a replica could be stripped, (3) resist the attack of etchants, (4) be incompatible with the replica material to permit stripping.

Of the mounting materials investigated, aerotex M-3, a water soluble melamine formaldehyde plastic, was found to be the easiest to use. A thick paste was made by mixing the powder in a little aerotex. A thin layer of this mixture was spread on a square of glass, about ½ in. on the side, thick enough to permit easy holding during polishing. The best final surface was obtained by spreading the mixture of powder in aerotex into a film as thin as possible. Under such a condition, the aerotex polymerizes into a continuous film that seems to gain strength from the glass backing. A thick layer of aerotex gives a porous rough surface after polymerization. Polymerization was carried out in a drying oven at 140°C for 2 hr. The specimens were then carefully polished and etched* in the ordinary man-

---

* Standard etchants were used as follows:

| Powder | Etchant |
|---|---|
| Tungsten | 10g NaOH, 10g $FeK_3(CN)_6$, 100cc water |
| Nickel | Merica's solution: $HNO_3$(70 pct) 50cc; $CH_3COOH$ (50 pct) 50cc |
| Iron | 2 pct nital |

All etchants were applied by flooding.

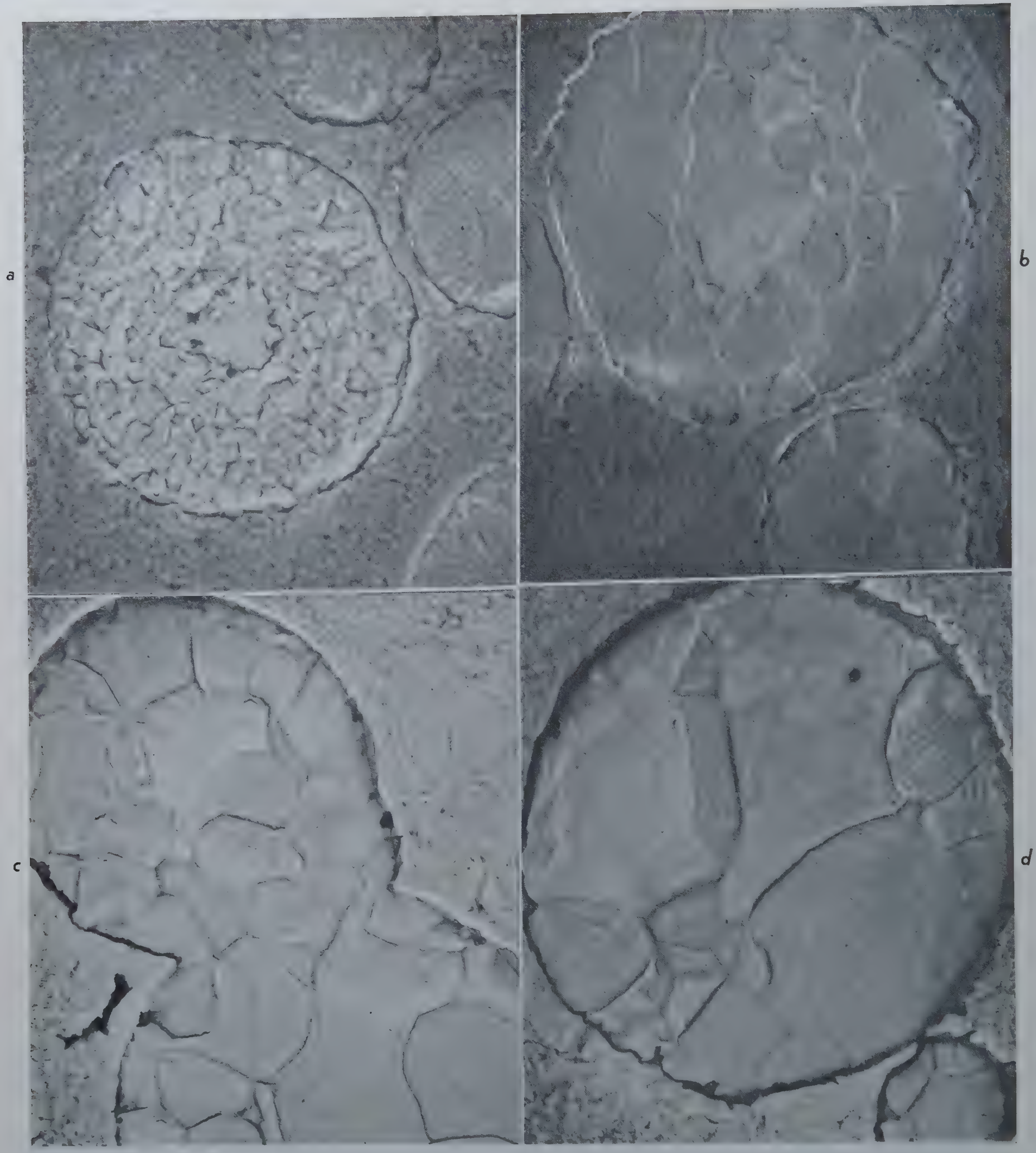

FIG 3—Particles of carbonyl iron powder illustrating differences in grain size. × 10,000. Slightly reduced in reproduction.

ner for metallographic work through emery papers, silk cloth and velvet. The usual precautions to prevent removal of inclusions from metallographic specimens had to be observed; consequently most of the polishing was carried out on the silk wheel with alumina from Linde Air Products Co. as an abrasive. Either formvar or parlodion replicas could be stripped from the surface and shadow-cast as is customary.

## Results

Fig 1 shows sections through particles of a sample of tungsten powder. The shape and microstructure of the particles are clearly visible. Evidently many aggregates actually consist of small particles sintered together; the sintering probably took place during reduction of the tungsten oxide in the preparation of the metal powder. The resolution power of the light microscope is not sufficient to permit such an observation. Examination with the electron microscope of the powder dispersed in the supporting film also fails to indicate whether the aggregates consist of separate particles just touching one another or of particles bonded together into actually much larger particles.

Fig 2 shows sections through particles of a sample of carbonyl nickel

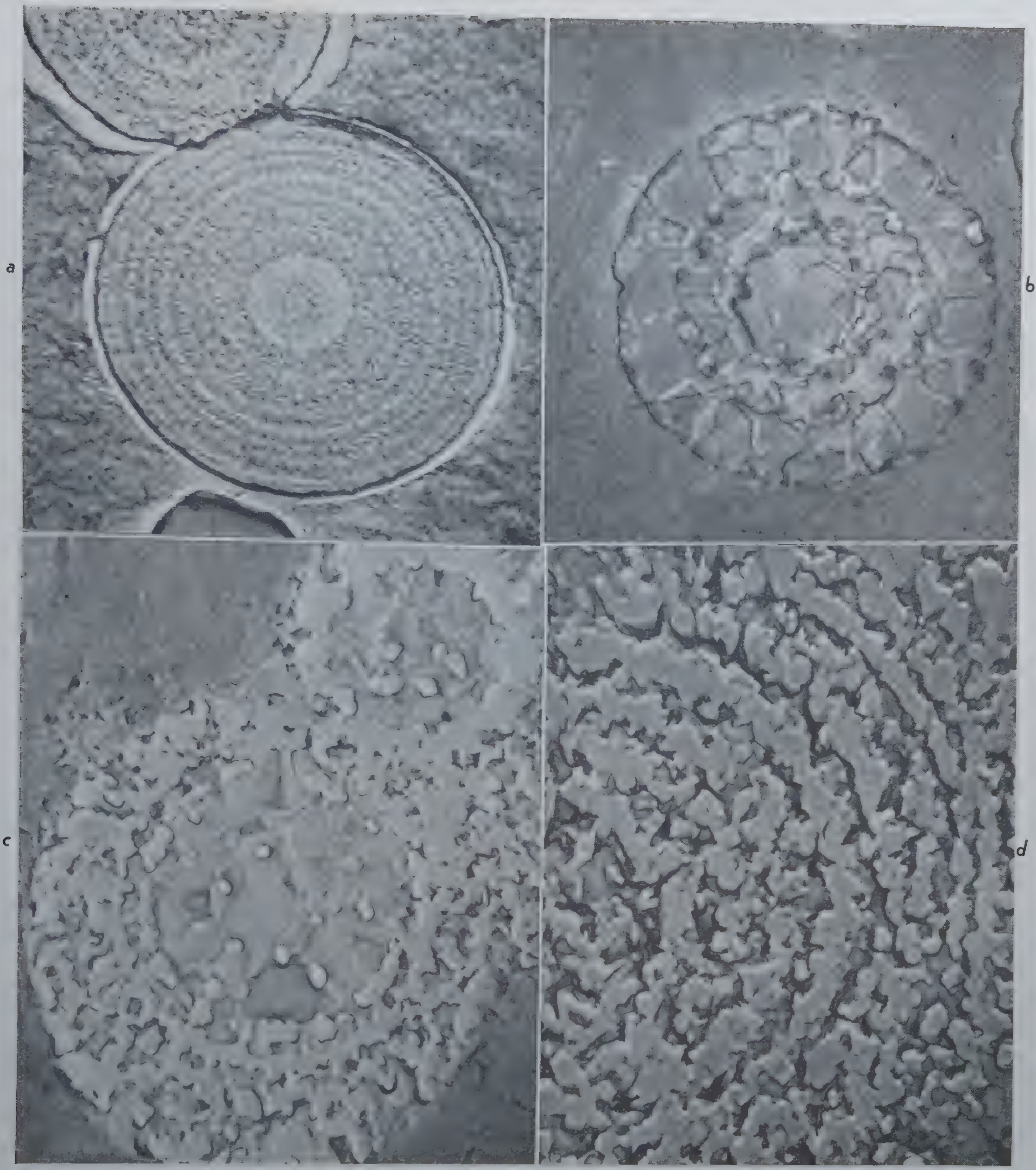

FIG 4—Particles of carbonyl iron powder illustrating differences in the structure. × 10,000. Slightly reduced in reproduction.

powder. In this case, the large specific area of the powder is evidenced by the jagged outline of the particles. Again the resolution power of the light microscope is too low to reveal the surface condition of the particles of such a powder. Examination with the electron microscope of the powder dispersed in the supporting film would also fail to bring out the surface details of the powder or would, at least, show them less clearly than replicas of the sections do.

Fig 3, 4 and 5 show sections through particles of a sample of carbonyl iron powder. The shape and microstructure of the particles are again clearly visible. The diversity in grain size and structure of the particles of a small sample of a powder is striking. Fig 3 illustrates differences in grain size; Fig 4 brings out differences in the structure of particles with the characteristic "onion skin" appearance: Fig 5 is a micrograph of the same particle as Fig 4*a* at a higher magnification; it emphasizes the presence of two finely dispersed constituents which are alternately in larger proportions forming concentric darker and lighter rings. The number and sharpness of the structural details visible with the electron microscope is greatly increased over those brought out with the ordinary microscope. From observations with the ordinary microscope, for instance, one might be temp-

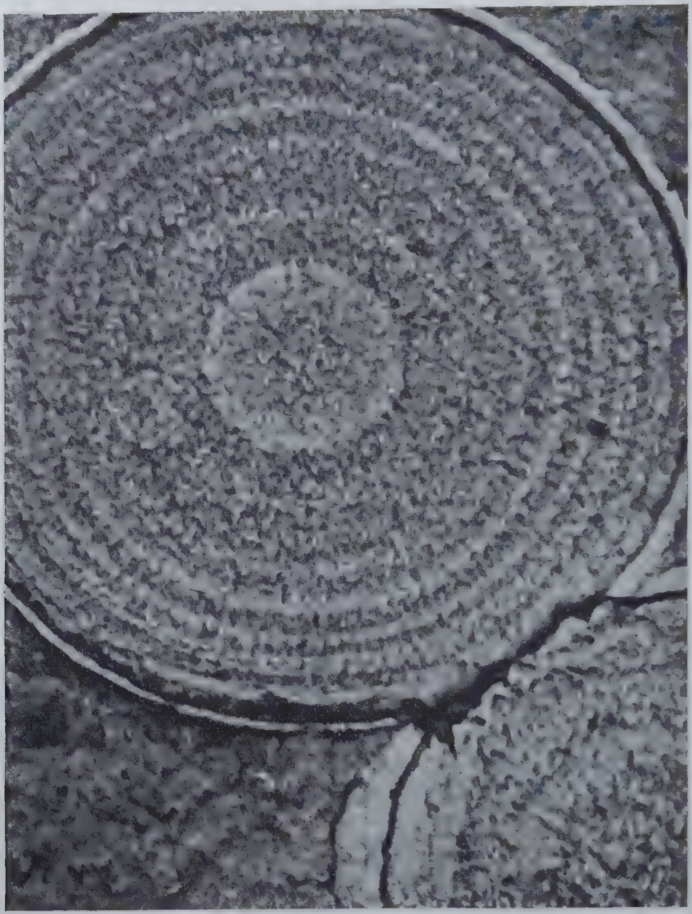

FIG 5—Particles of carbonyl iron powder. Micrograph of Fig 4*a* at a higher magnification. × 15,000.

ted to exaggerate the occurrence of particles with an "onion skin" structure and to attribute the absence of such a structure in a large number of particles to improper etching. Really many particles consist of polyhedral grains of iron too small to be resolved with the light microscope.

## Conclusions

The micrographs in this paper prove that the application of the electron microscope to the study of fine metal powders can be extended to the examination of sections of the particles. The microstructure of such particles can thus be revealed beyond the range of resolution of the light microscope. Added information can also be obtained on the size, shape and surface condition of metal particles by a study of their cross-sections with the electron microscope over the information obtainable with the same instrument from a study of the powders dispersed in supporting films.

## Acknowledgment

The author is grateful to Sylvania Electric Products, Inc. for its generous support of this work. The author also wishes to extend her thanks to Mr. W. E. Kingston, Manager of Metallurgical Research, for his patient guidance, to Mr. G. A. Davis, Section Head of Physical Metallurgy, for his assistance and constructive criticism, and to Dr. B. Kopelman, Section Head of Basic Research, for his advice on plastics.

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# The Effect of Ferrite Grain Size on Notch Toughness

J. M. HODGE,* R. D. MANNING,* Members AIME, and H. M. REICHHOLD*

## Introduction

THE work reported in this paper represents the first of a series of investigations of the factors governing notch toughness in ferritic materials. This paper is concerned with two of these factors, namely, the effect of ferrite grain size, and the effect of an alloy content of 3.64 pct nickel. Every effort has been made to hold other variables constant in order to isolate the effects of these two. The compositions chosen for study were 0.02 pct carbon in order to eliminate the variable of carbide distribution, one steel being a plain carbon steel and the other alloyed with 3.64 pct nickel. Both steels were fully killed with silicon, without an aluminum addition, so that the variable of deoxidation practice was held constant. Finally, all samples were water quenched from 1200°F and tempered 24 hr at 300°F in order to hold the quench aging variable constant and to decrease the tendency for grain boundary carbide precipitation.

The ferrite grain size was varied by heat treatment over the range of A.S.T.M. grain size numbers of about 2 to 6 in each steel so that the effect could be evaluated individually and the notch toughness of each steel could be compared at comparable ferrite grain sizes.

*Table 1 . . . Composition of Steels—Per Cent*

| Heat No. | C | Mn | P | S | Si | Ni | Al (acid sol.) | N* | O* |
|---|---|---|---|---|---|---|---|---|---|
| 3539 | 0.02 | 0.52 | 0.009 | 0.018 | 0.17 | 0.03 | 0.009 | 0.002 | 0.019 |
| 3537 | 0.02 | 0.55 | 0.011 | 0.017 | 0.18 | 3.64 | 0.006 | 0.005 | 0.018 |

* By vacuum fusion analysis.

## Materials and Experimental Procedure

### MATERIALS

The materials for this investigation were obtained from Battelle Memorial Institute as 250 lb induction melts which were forged into 1½ in. square bars and then rolled into 0.6 in. square bars. Both steels were deoxidized with silicon, the aluminum content being held to a minimum. Check analyses of these materials are shown in Table 1.

### HEAT TREATMENT FOR GRAIN SIZE

The grain size was varied by varying both the cooling rate and the austenitizing temperatures. The heat treatments used and the corresponding grain size values are tabulated in Table 2.

A semicontinuous network of grain boundary carbide was observed in the microstructure of both the plain carbon and nickel steels in the as rolled condition and an additional heat treatment was necessary to eliminate this variable. Therefore, all samples were water quenched from 1200°F and tempered 24 hr at 300°F as a final treatment before testing. This heat treatment served to eliminate to a great extent the grain boundary carbide network and to hold the quench aging effect constant.

### IMPACT TESTING

Standard keyhole Charpy impact tests were machined after heat treatment. A bath of acetone and dry ice was used for refrigeration of the samples down to temperatures of −94°F (−70°C) and a bath of either methylcyclohexane or isopentane, cooled by

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TP 2553 E. Discussion of this paper (2 copies) may be sent to *Transactions* AIME before Dec. 15, 1949. Manuscript received Nov. 1, 1948; revision received Dec. 18, 1948.

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FIG 1—Microstructure of rapidly cooled plain carbon steel, Heat 3539, Code C, illustrating ferrite grain size of 5. Nital etch. × 100.

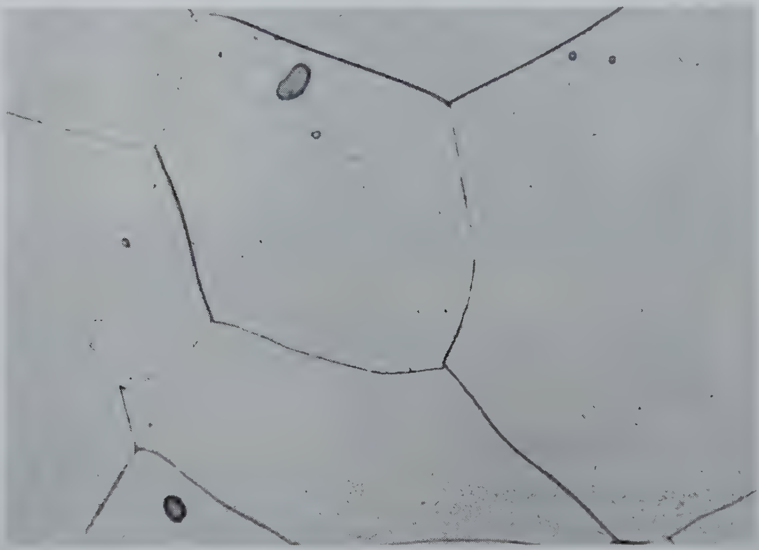

FIG 2—Microstructure of rapidly cooled plain carbon steel, Heat 3539, Code C. Nital etch. × 1000.

*Table 2 . . . Summary of Heat Treatments and Corresponding Hardness Ferrite Grain Size, and Transition Temperature*

| Heat No. | Code | Austenitizing Temperature, °F | Cooling Method | Hardness RB | Ferrite Grain Size No. | Transition Temperature, °F |
|---|---|---|---|---|---|---|
| 3539 | B | 1800 | Quenched in lead at 1300°F, held 2 hr—air cooled | 61 | 5 (4–6) | − 88 ± 12 |
| 3539 | C | 1700 | Quenched in lead at 1000°F, held 15 min.—air cooled | 63 | 5 (4–6) | − 82 ± 12 |
| 3539 | M | 1700 | Quenched in brine | 63 | 5 (4–7) | − 73 ± 14 |
| 3539 | K | 2000 | Quenched in brine | 62 | 3–4 (2–5) | − 20 ± 35 |
| 3539 | S |  | AS ROLLED | 62 | 3–4 (3–5) | − 39 ± 16 |
| 3539 | A | 1800 | Furnace cooled at 20°F per hr to 1000°F—air cooled | 48 | 2–3 (2–4) | − 12 ± 17 |
| 3539 | R | 2000 | Furnace cooled at 20°F per hr to 1000°F—air cooled | 51 | 1–2 (0–3) | ± 45 ± 25 |
| 3537 | V | 1650 | Quenched in brine | 77 | 6 (5–7) | −177 ± 17 |
| 3537 | N | 1650 | Air cooled | 76 | 6 (5–7) | −171 ± 19 |
| 3537 | E |  | AS ROLLED | 77 | 5 (4–6) | −133 ± 14 |
| 3537 | H | 1950 | Quenched in lead at 1100°F, held 2 hr—air cooled | 76 | 4–5 (4–6) | −112 ± 16 |
| 3537 | D | 2200 | Furnace cooled at 20°F per hr to 1000°F—air cooled | 72 | 3 (2–4) | − 85 ± 13 |
| 3537 | T | 2400 | Furnace cooled at 20°F per hr to 1000°F—air cooled | 73 | 2 (0–4) | − 57 ± 16 |

Notes:

After above treatments all bars were heated at 1200°F for one-half hour and water quenched, and then were heated for 24 hr at 300°F and air cooled.

Numbers in parentheses under Ferrite Grain Size Number refer to the range of grain sizes present.

liquid nitrogen, was used for the lower temperatures. Wherever possible, three tests were broken at a given temperature. In the vicinity of the beginning and ending of the transition temperature range, testing was conducted in such a way as to restrict the testing interval to 10°F. The appearance of the fracture was noted on each test and was recorded in terms of the percent of the area which showed a cleavage type of fracture.

### ESTIMATION OF FERRITE GRAIN SIZE

The ferrite grain size was estimated by comparison of the microstructure at a magnification of 100 with standard grain size charts. The grain size reported is the predominant grain size, as a range of grain sizes was present in most samples. The values represent an average of the estimations of three independent observers.

### HARDNESS MEASUREMENT

Rockwell B hardness measurements were made on impact samples from each heat treatment.

### END-QUENCH TESTS

Standard ½ in. end-quench tests, austenitized at 1700°F, were made on each steel to study the effect of cooling rate on ferrite grain size. Ferrite grain size as a function of the distance from the quenched end of the bar was determined by metallographic examination.

## Results and Discussion

### MICROSTRUCTURE

Typical microstructures of the two steels after the final treatment are shown in Fig 1–4.

### RELATIONSHIPS AMONG FERRITE GRAIN SIZE, NICKEL CONTENT, TRANSITION TEMPERATURE AND IMPACT VALUES

Plots of the impact values as a function of testing temperature for each of the steels at each grain size value are shown in Fig 5–17. The corresponding transition temperature was determined from each of these plots. This was defined as the middle of the temperature range over which an impact value of 40 ft-lb was obtained. These temperatures and the temperature ranges at 40 ft-lb for each of the conditions are tabulated in Table 2. The value of 40 ft-lb was chosen as a criterion inasmuch as most of the actual test results fell either below or above this value and it therefore represents the point at which the energy is changing most rapidly with changes in transition temperature.

The transition temperature values for the two steels are plotted as a function of ferrite grain size in Fig 18. A straight line relationship between ferrite grain size and transition temperature for each of the steels is indicated by these results. An increase of ferrite grain size of one A.S.T.M. grain size number is thus seen to raise the transition temperature by 30°F in each steel. The transition temperature of the 3.64 pct nickel steel is, however, 60°F lower at a given ferrite grain size than the plain carbon steel, even though the nickel steels are at a somewhat higher hardness level. Inasmuch as the other variables were held constant, this improvement in notch toughness, represented by the lower transition temperatures of the nickel steels, is apparently a specific effect of nickel as an alloying element in ferrite.

The average impact values at room temperature for both steels are plotted as a function of ferrite grain size in Fig 19. A fair correlation also exists between these room temperature values and ferrite grain size, an increase in ferrite grain size of one A.S.T.M. grain size number decreasing the impact value by approximately 8 ft-lb. This relationship, however, appears to be independent of nickel content, as the nickel steel does not show consistently higher impact values than the plain carbon steel at a given grain size level.

FIG 3—Microstructure of rapidly cooled nickel steel, Heat 3537, Code N, illustrating ferrite grain size of 6. Nital etch. × 100.

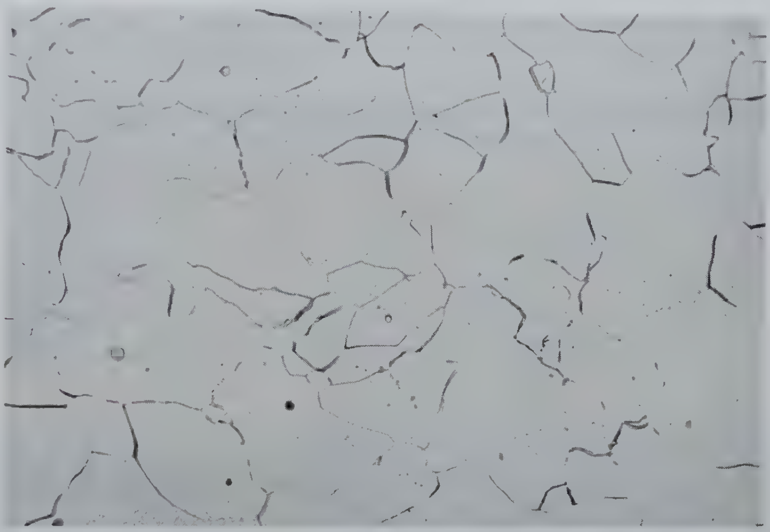

FIG 4—Microstructure of rapidly cooled nickel steel, Heat 3537, Code N. Nital etch. × 1000.

## FACTORS GOVERNING FERRITE GRAIN SIZE

The range of ferrite grain sizes studied in this investigation was obtained by varying both the austenitizing temperature and the cooling rate. The relationships among austenitizing temperature, cooling rate and ferrite grain size for the steels of this investigation are summarized in Fig 20. It was found that, at a constant cooling rate, the ferrite grain size changed rather slowly with changes in austenitizing temperature, an increase in austenitizing temperature from 1800 to 2000°F corresponding to an increase in ferrite grain size of about one grain size number. Increasing the cooling rate, however, was much more effective in decreasing the ferrite grain size of the plain carbon steel than that of the nickel steel. Increasing the cooling rate from a furnace cool at 20°F per hr to a brine quench, decreased the ferrite grain size of the plain carbon steels by approximately two grain size numbers, while a similar change in cooling rate resulted in a decrease of only one grain size number for the nickel steel.

The effect of cooling rate on the ferrite grain size in the two steels was further evaluated by end quench tests. One-half inch diameter specimens were used because of the size limitation, and the standard procedure for ½ in. end quench tests was followed. The specimens of both steels were austenitized at 1700°F, and the results are plotted in Fig 21 in terms of ferrite grain size as a function of distance from the quenched end. Here again, the plain carbon steel shows a much more pronounced effect of cooling rate on ferrite grain size than does the nickel steel.

The above results are explainable on the basis that the ferrite grain size for a given austenite grain size reflects the average temperature at which ferrite precipitates during cooling. The slower transformation rate of the nickel ferrite would thus result in a lower average temperature of ferrite precipitation at a given cooling rate and a correspondingly smaller, final ferrite grain size. Furthermore, the differences in the effect of cooling rate on ferrite grain

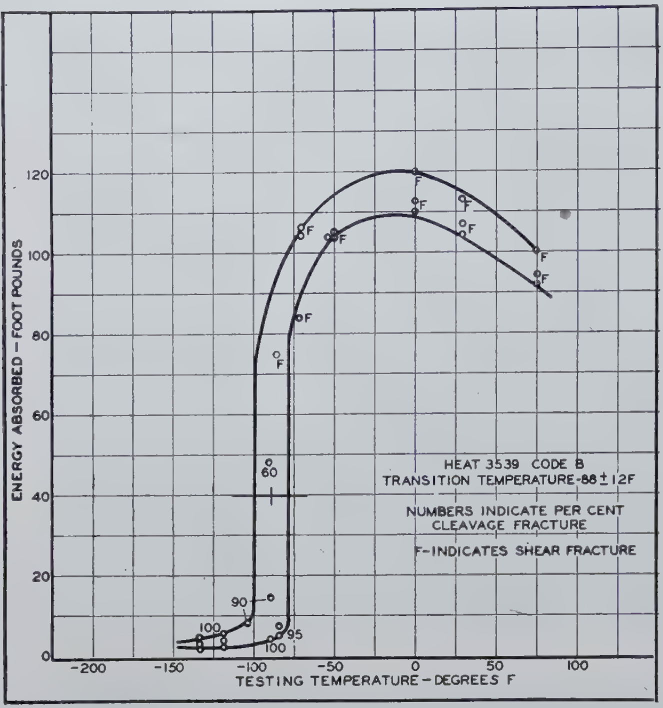

FIG 5—Impact-temperature curve for plain carbon steel at a ferrite grain size of 5.

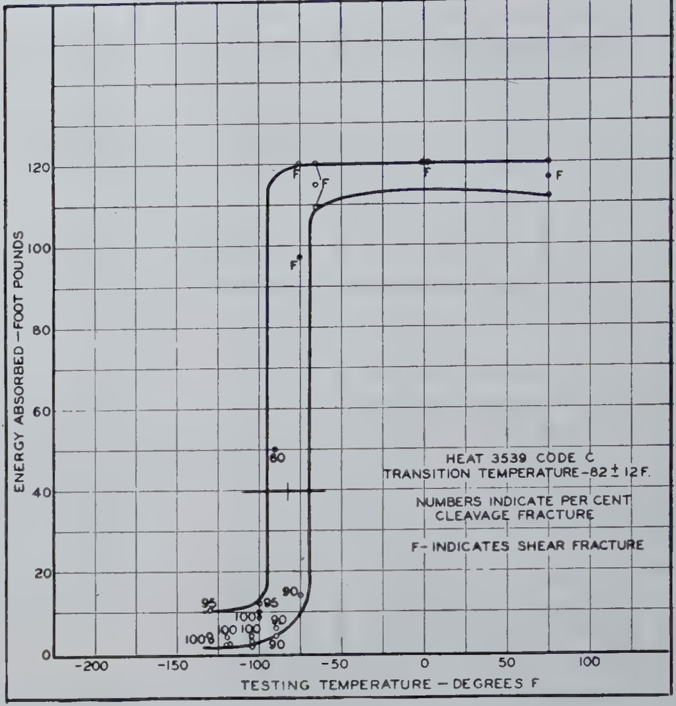

FIG 6—Impact-temperature curve for plain carbon steel at a ferrite grain size of 5.

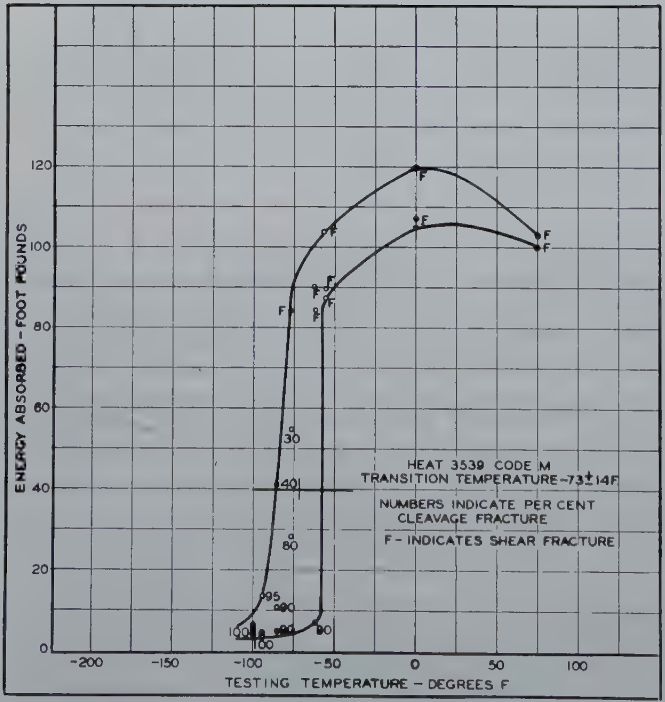

FIG 7—Impact-temperature curve for plain carbon steel at a ferrite grain size of 5.

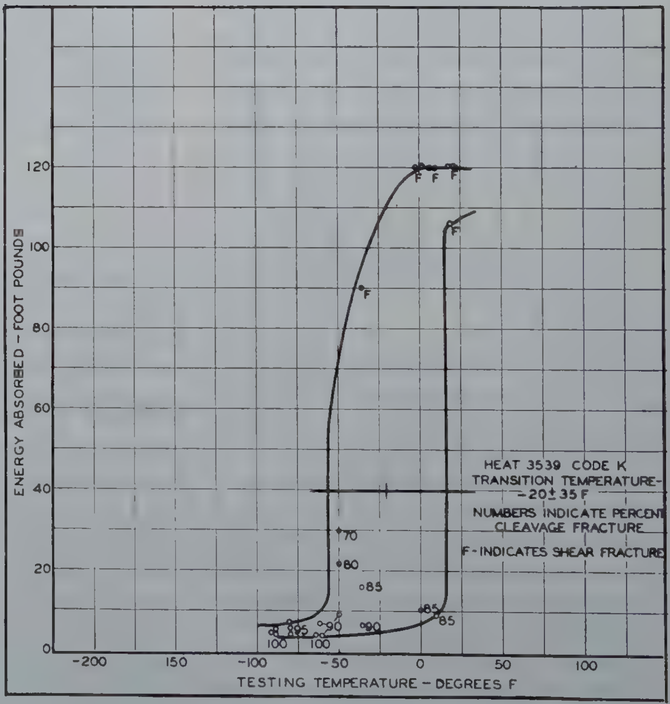

FIG 8—Impact-temperature curve for plain carbon steel at a ferrite grain size of 3–4.

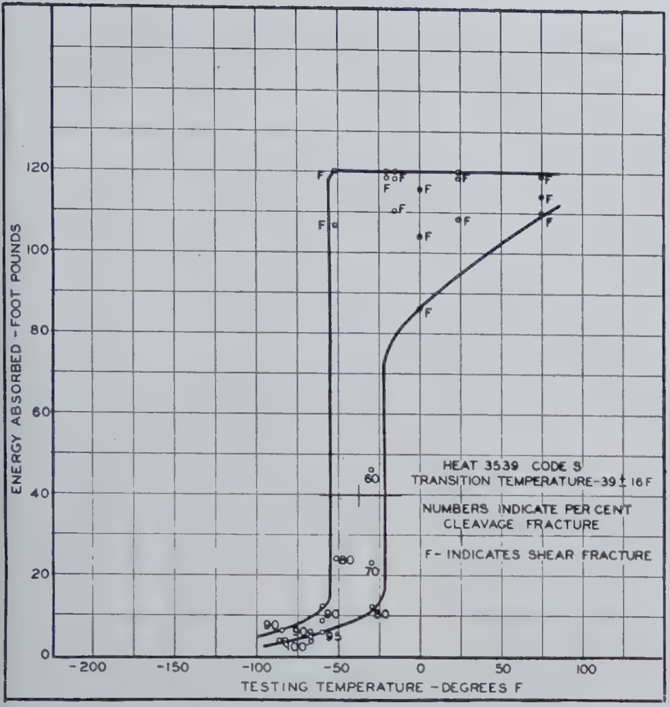

FIG 9—Impact-temperature curve for plain carbon steel at a ferrite grain size of 3–4.

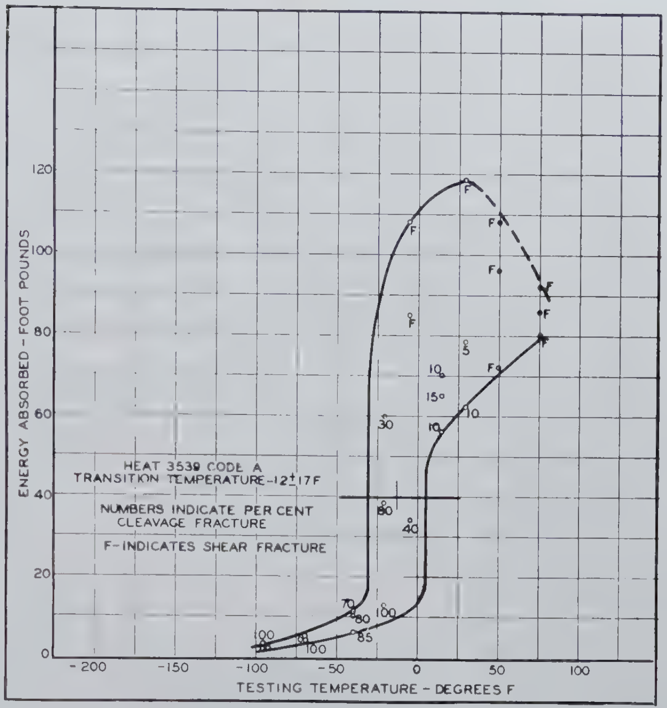

FIG 10—Impact-temperature curve for plain carbon steel at a ferrite grain size of 2–3.

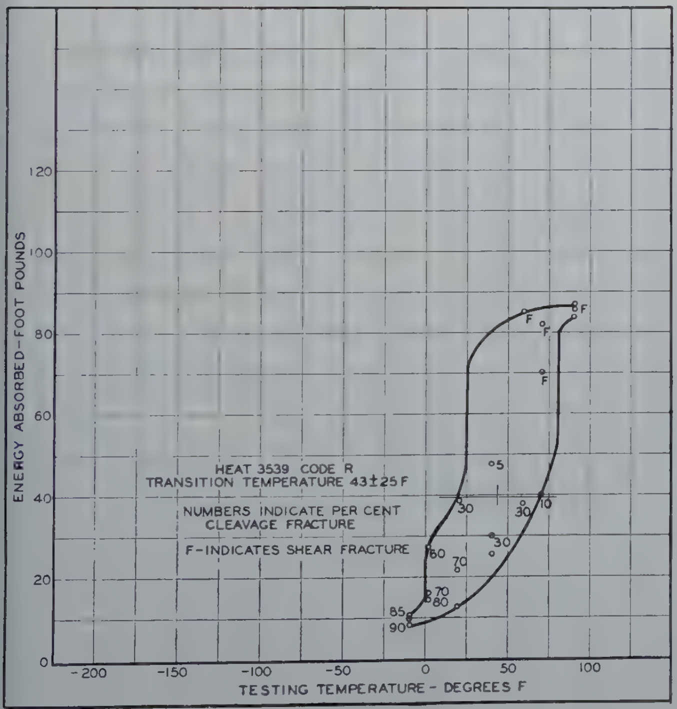

FIG 11—Impact-temperature curve for plain carbon steel at a ferrite grain size of 1–2.

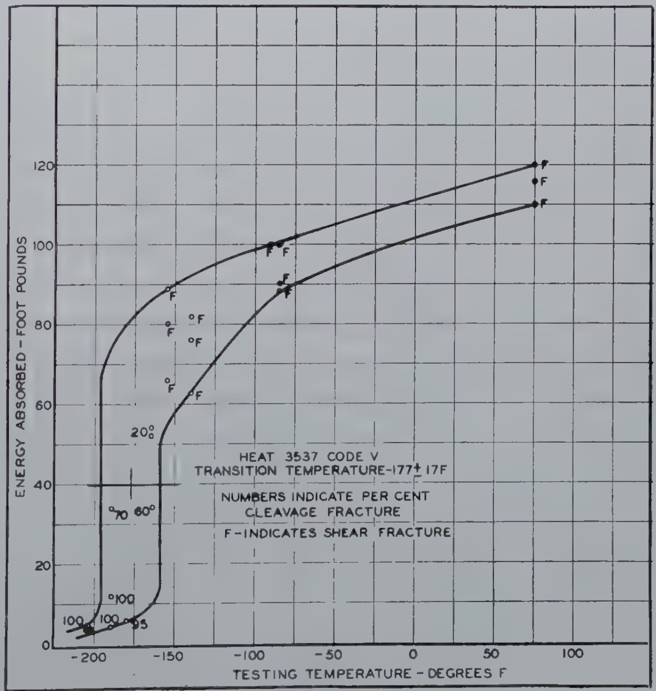

FIG 12—Impact-temperature curve for nickel steel at a ferrite grain size of 6.

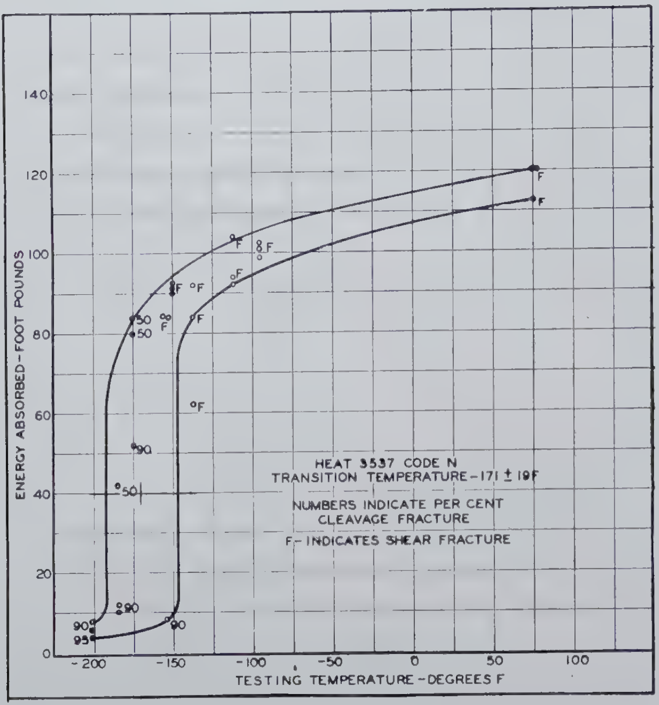

FIG 13—Impact-temperature curve for nickel steel at a ferrite grain size of 6.

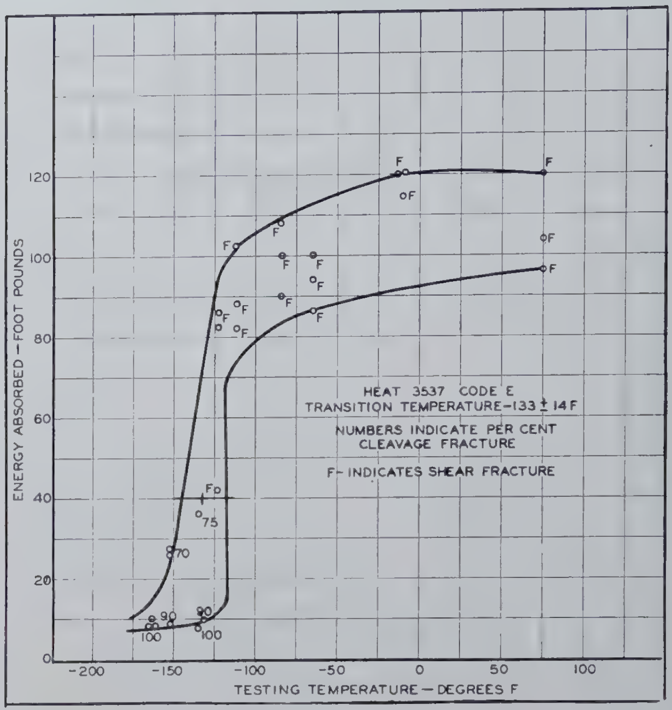

FIG 14—Impact-temperature curve for nickel steel at a ferrite grain size of 5.

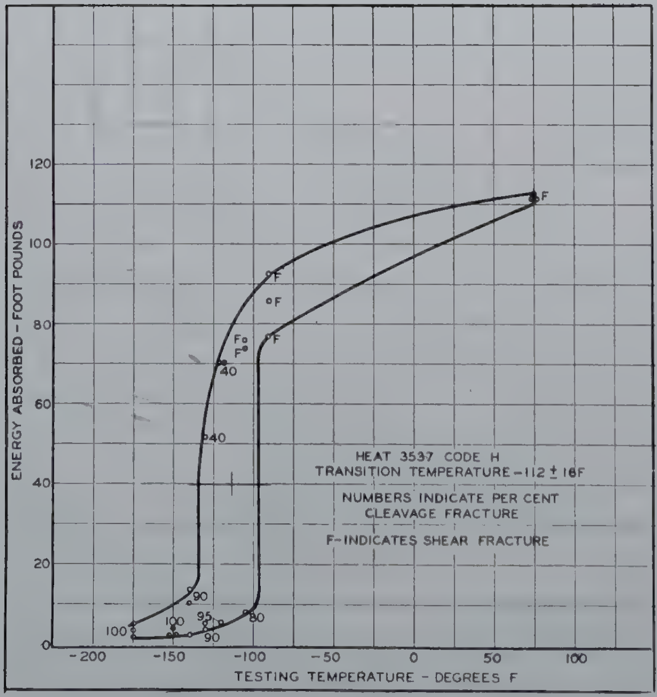

FIG 15—Impact-temperature curve for nickel steel at a ferrite grain size of 4–5.

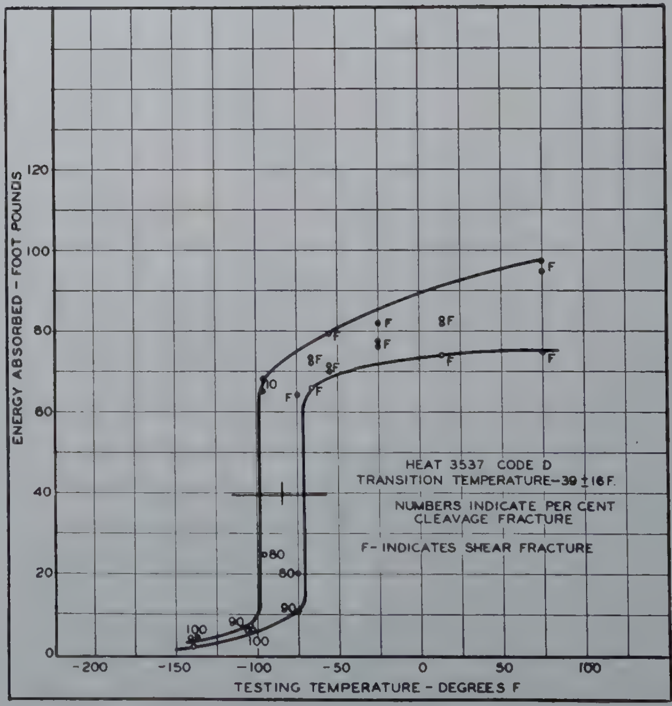

FIG 16—Impact temperature curve for nickel steel at a ferrite grain size of 3.

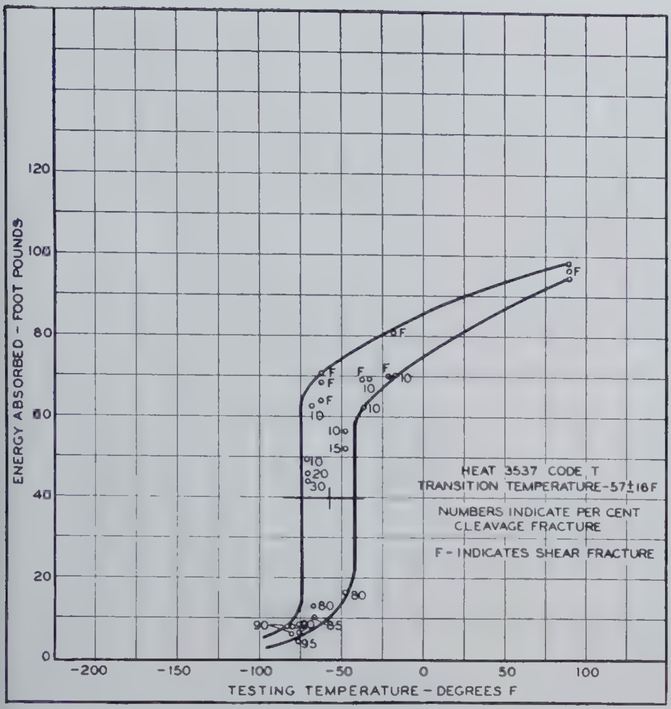

FIG 17—Impact-temperature curve for nickel steel at a ferrite grain size of 2.

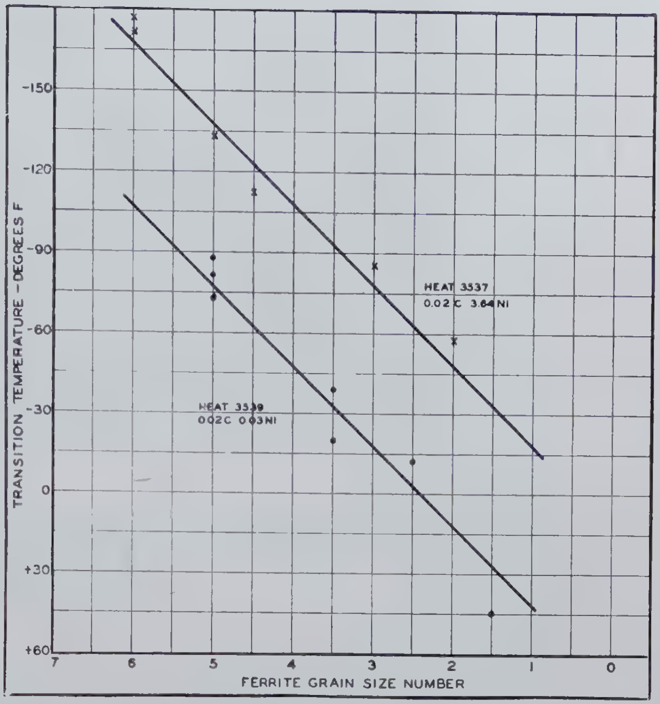

FIG 18—Transition temperature as a function of ferrite grain size of a plain carbon and a nickel steel.

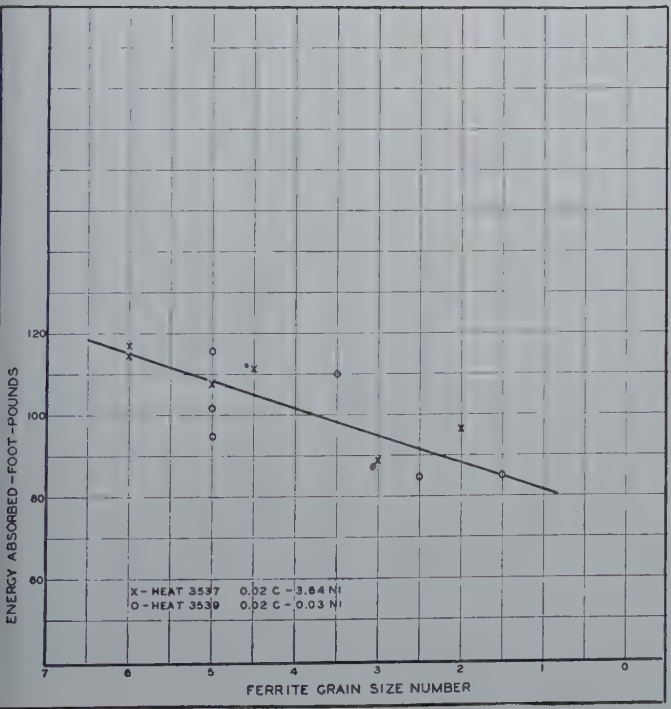

FIG 19—Energy absorption at room temperature as a function of ferrite grain size.

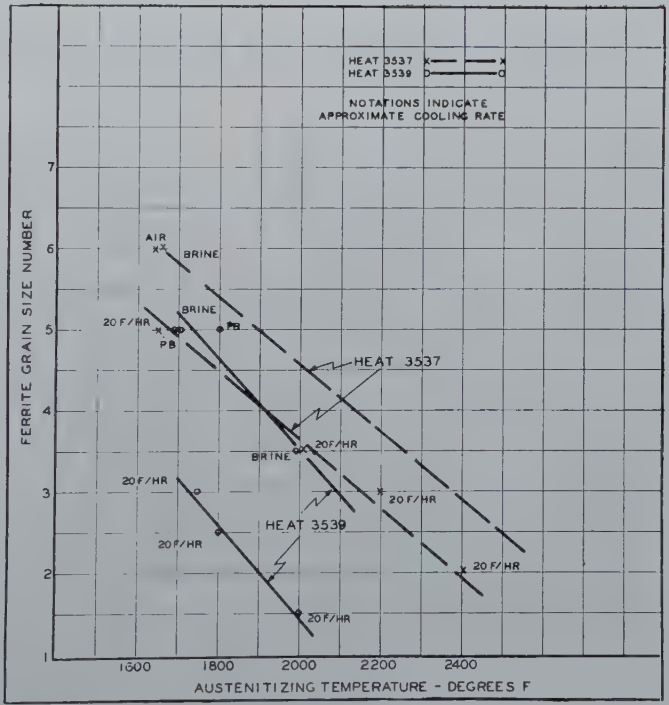

FIG 20—Relationship among austenitizing temperature, ferrite grain size and cooling rate.

size would be expected to be larger at the slower cooling rates inasmuch as the differences in transformation rates to ferrite between nickel and plain carbon steels are generally more pronounced at the higher transformation temperatures.

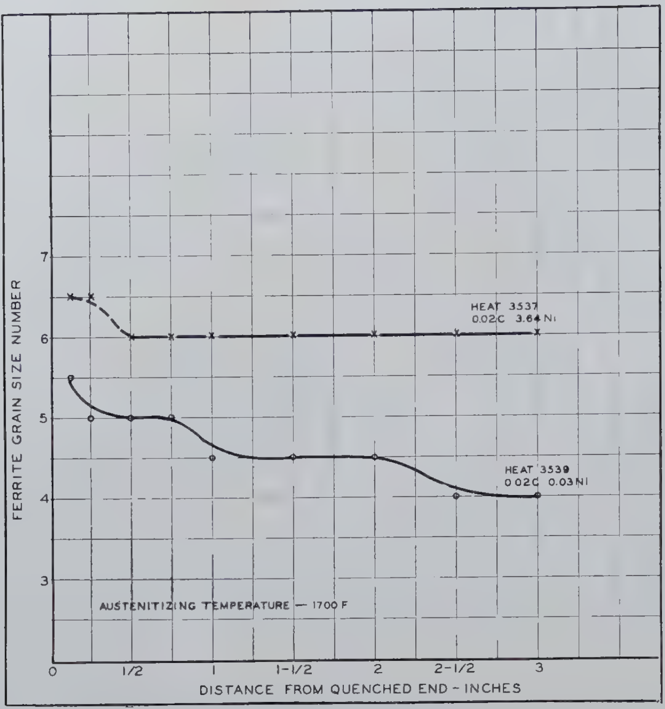

FIG 21—Ferrite grain size as a function of cooling rate in ½-in. diam end-quench tests.

## Conclusions

1. The keyhole notch Charpy transition temperature of 0.02 pct carbon steels is a straight line function of the ferrite grain size, the transition temperature being raised 30°F by an increase in ferrite grain size of one A.S.T.M. grain size number.
2. The keyhole notch Charpy transition temperature is lowered 60°F at a constant ferrite grain size in 0.02 pct carbon steels by alloying with 3.64 pct nickel.
3. The room temperature impact value in the keyhole Charpy impact test for each steel is also a function of the ferrite grain size, increasing as the grain size decreases.
4. At a given ferrite grain size, the room temperature impact value in the keyhole Charpy impact test is unaffected by alloying with 3.64 pct nickel.

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# Effect of Recrystallization Texture on Grain Growth

By PAUL A. BECK,* Member AIME, and PHILIP R. SPERRY*

It has been shown[1] that in polycrystalline strips of high purity aluminum with a fairly random orientation distribution, grain growth progresses gradually until the average grain diameter reaches a value approximately equal to the strip thickness. Recent work at this laboratory led to the realization that grain growth might be impeded to a considerable extent in the presence of a sharply defined texture, where orientation differences between neighboring grains are small.

In order to investigate this effect the following experiment was carried out with the same lot of high purity aluminum previously used for grain growth studies in randomly oriented material.[1] Very large grain size was developed by grain growth at 650°C in specimens of 0.200 in. thickness. These specimens were then rolled to a thickness of 0.050 in. or 1.25 mm—a reduction of 75 pct. In the rolled strip each large grain corresponded to an elongated area easily identified by etching. After annealing for 1 to 25 min at 600°C and re-etching, these elongated areas were again recognizable. Within each area, corresponding to a single large grain before annealing, there formed by recrystallization a multitude of new grains with a fairly well developed preferred orientation. The orientation and the size of the new grains formed in areas corresponding to different large grains, varied widely depending on the orientation of the parent grains with respect to the rolling direction and the plane of rolling. Many areas were found where the average grain size was considerably smaller than the specimen thickness. Such an area occurred in a specimen cut in half before annealing. One half, containing a portion of the area in question, was annealed 1 min at 600°C, the other half, with the remaining portion of this area, for 25 min at the same tempera-

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* Associate Professor and Metallographer, respectively, Department of Metallurgy, University of Notre Dame.

[1] References are at the end of the paper.

ture. It was apparent that the annealing time had very little effect on the size of the small grains produced by recrystallization from a single large grain of the original rolled specimen. They possessed a very well developed preferred orientation, which made it somewhat difficult to detect the grain boundaries for accurate grain size determination. However, after some experimentation, it was found possible to make fairly accurate determinations. These are presented in the Table 1, which also includes for comparison the grain sizes obtained by similar anneals in specimens from the same bar of aluminum, rolled to the same final thickness, but exhibiting little preferred orientation (penultimate condition: fine grained, polycrystalline; last reduction: 33 pct).

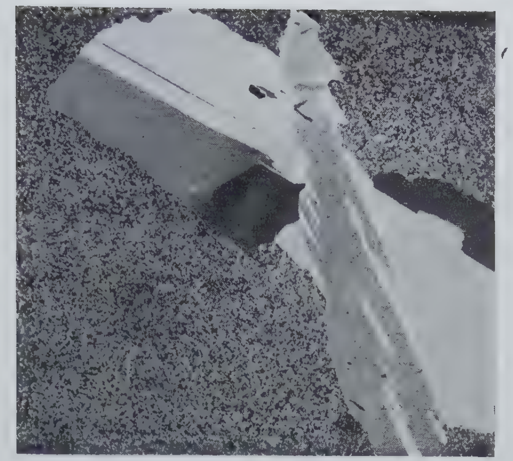

FIG 1—Partially coarsened tough pitch copper specimen, cold rolled 90 pct, annealed 3 min. at 1000°C. Magnification 5 ×. (Reduction approximately one-half.)

***Table 1 . . . Effect of Annealing Time and Orientation on Grain Size***

| Annealing Conditions | Average Grain Size, mm | |
|---|---|---|
| | Strong Preferred Orientation | Random Orientation |
| 1 min at 600°C..... | 0.33 | 0.61 |
| 25 min at 600°C.... | 0.36 | 1.0 |

The fact that with a strong texture the grain size remained practically constant from 1 to 25 min at 600°C, at a value much smaller than the specimen thickness, proves that in a highly oriented aggregate of crystals, grain growth is greatly reduced, if not entirely impeded. It is quite possible that this reluctance of grains to grow, even though they are small, when their orientations are very nearly the same, is a result of the low surface tension values associated with grain boundaries under such conditions.[2]

The close connection between a certain type of coarsening and the inhibition of gradual grain growth by a dispersed second phase has been known for a long time.[3] These relationships were recently explored in a quantitative and rather detailed manner.[4] However, from the results of Dahl and Pawlek[5] and of Cook and Macquarie[6] it may be concluded[4,7] that in certain metals coarsening may also occur *without* a dispersed second phase, provided that the conditions of penultimate grain size, of amount of reduction by rolling, and of composition are such that a strongly developed cube texture results upon recrystallization. This texture, in which the fine recrystallized grains have very closely identical orientation, appears to resist gradual grain growth up to relatively high temperatures. In copper with the cube recrystallization texture, extremely coarse grains abruptly develop when the temperature is raised to approximately 1000°C (see Fig 1). These very large grains have a fairly well developed preferred orientation of their own,[5,8] different from that of the fine grained recrystallized matrix in which they grow. This fact may be interpreted as an indication that in a highly oriented fine grained matrix, the rate of growth of a grain strongly depends on its orientation with respect to the preferred orientation of the matrix. The alternative interpretation, namely, that the preferred orientation of the coarse grains is a result of the presence in the matrix of "nuclei" of a certain orientation only[8] appears less convincing. It seems justified to assume that "texture-dependent coarsening" is intimately connected with the above described restraint of gradual grain growth by virtue of a strongly developed texture, just as "inhibition-dependent coarsening" is connected with grain growth inhibition by a dispersed second phase.

This work was supported by the Office of Naval Research, Contract No. N6 ori-165, T.O. no. 1.

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# Recrystallization and Microstructure of Aluminum Killed Deep Drawing Steel

R. L. RICKETT,* Member, S. H. KALIN,† and J. T. MACKENZIE, JR.,‡ Junior Member AIME

Aluminum killed low carbon steel,§ which is now used extensively for severe deep drawing or other difficult forming operations, is unusual in that its grain structure, after cold reduction and box annealing in accordance with conventional continuous sheet or strip mill practice, often is elongated, although at times it is equiaxed. Since this unusual structure has been found superior for many, but not all, severe forming operations, recrystallization of the steel, both at constant temperature and on continuous heating, was investigated and compared with that of rimmed steel in the hope that something might be learned about the mechanism of, and the factors controlling, the formation of such elongated grains.

In this structure, the grains are elongated both in the lengthwise direction of the strip and transverse to this direction, even though nearly all of the extension in both hot and cold rolling is in the lengthwise direction. The grains are thus roughly pancake-shaped, being longer and wider than they are thick, as observed also by Burns and McCabe,[1] and as illustrated by the typical structures shown in Fig 1. Fig 1*a*, representing a conventional longitudinal section, shows the length and thickness of the grains, whereas Fig 1*b* shows their length and width as seen by examining a section parallel to the sheet surface. Both illustrate the very irregular grain boundaries usually associated with the elongated grain shape. A finer equiaxed grain structure in this same grade is shown in Fig 1*c*. Either the elongated or the equiaxed structure may be present in the annealed product, and in rare instances the two types may coexist in a single specimen, as shown in Fig 1*d*.

*Table 1 . . . Composition of Steels Investigated*

| Steel | Type | | Composition—Pct* | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | C | Mn | P | S | Si | Al | $Al_2O_3$ |
| A | Rimmed | Hot rolled strip 0.095 in. thick | 0.07 | 0.36 | 0.008 | 0.024 | 0.008 | 0.008 | 0.005 |
| B | Al. Killed | Hot rolled strip 0.075 in. thick | 0.05 | 0.32 | 0.010 | 0.025 | 0.010 | 0.09 | 0.008 |
| C | Al. Killed | Hot rolled strip 0.075 in. thick | 0.04 | 0.34 | 0.010 | 0.023 | 0.008 | † | † |
| D | Al. Killed | Hot rolled strip 0.085 in. thick | 0.05 | 0.30 | 0.012 | 0.028 | 0.008 | 0.08 | 0.008 |
| E | Al. Killed | Hot rolled strip 0.085 in. thick | 0.05 | 0.32 | 0.010 | 0.022 | 0.010 | 0.08 | 0.007 |
| F | Al. Killed | Cold rolled strip 0.053 in. thick (40 pct red.) | 0.05 | 0.33 | 0.008 | 0.023 | 0.010 | † | † |
| G | Al. Killed | Cold rolled strip 0.053 in. thick (45 pct red.) | 0.05 | 0.33 | 0.006 | 0.023 | 0.008 | 0.05 | 0.012 |
| H | Al. Killed | Cold rolled strip 0.053 in. thick (45 pct red.) | 0.06 | 0.39 | 0.007 | 0.021 | 0.006 | 0.06 | 0.014 |

* Values underlined are check analyses, others are heat analyses.

† Al and $Al_2O_3$ in these steels not determined but the heats were made by the same practice as the other aluminum killed steels.

## Isothermal Recrystallization of Rimmed and Aluminum Killed Steel

An aluminum killed steel known to have an elongated grain structure after conventional processing (Steel *B*, Table 1), was selected for the initial recrystallization studies; for comparison, a rimmed steel, *A* in Table 1, was used. Samples of each in the form of hot rolled strip 0.075 and 0.095 in. thick, respectively, were cold rolled on a small laboratory mill in steps of about 0.010 in. per pass to obtain total reductions of 40 and 60 pct. Small pieces of the cold reduced strip were heated in lead at selected constant temperatures for one of several periods of time, then cooled in air. Rate of heating in the lead was, of course, very fast. Hardness of the cooled specimen was measured and a longitudinal section examined metallographically.

Isothermal recrystallization curves for these two steels at 1050°F, based on hardness of the air cooled specimens, are shown in Fig 2 in which the amount of recrystallization corresponding to each plotted point is indicated. The marked difference in the behavior of these two types of steel is evident. After a corresponding amount of cold reduction, the rimmed steel recrystallizes in a much shorter time than the killed steel and the shape of its recrystallization curve, (plotted on a logarithmic time scale), is very different. The curve for rimmed steel indicates that recrystallization is analogous to isothermal transformation of austenite in that it proceeds at a progressively faster rate up to some 50 pct recrystallization, then at an increasingly slower rate. For the aluminum killed steel, however, the start of

Cleveland Meeting, October 1949.
TP 2552 E. Discussion of this paper (2 copies) may be sent to *Transactions* AIME before Dec. 15, 1949. Manuscript received October 26, 1948.

[1] References are at the end of the paper.

* Research Laboratory, United States Steel Corporation, Kearny, N. J.

† Carnegie-Illinois Steel Corporation, Gary Sheet and Tin Mill, Gary, Ind.

‡ United States Steel Export Co.

§ This type of steel comes within the special killed steel category of the American Iron and Steel Institute; cf. AISI Steel Products Manual, Sections 11, 12, and 13.

recrystallization is followed by a period during which little further change occurs, after which recrystallization of the remaining cold worked metal proceeds at a relatively fast rate. The hardness curve thus exhibits an initial gradual drop, then a nearly horizontal portion or "shelf" and finally a rather sharp drop. The "shelf" is lowered by increased cold reduction and, as discussed later, by increased temperature.

These two types of steel also differ considerably in microstructure both during and after recrystallization, as shown in Fig 3 and 4. In rimmed steel, Fig 3, the first recrystallized grains are nearly equiaxed, and remain so as they grow and new grains continue to form. In the aluminum killed steel however, Fig 4, the small new grains, which may be equiaxed as first formed, become elongated as they grow, apparently because resistance to growth in the thickness direction of the sheet is greater than in the lengthwise or crosswise direction. Both rate of growth and rate of formation of new grains (nucleation) are much less in the aluminum killed than in the rimmed steel.

Grain growth restraint in the aluminum killed steel appears to be greatest at boundaries of the cold worked grains, as illustrated in Fig 5. Even in the rimmed steel, Fig 5*a* and 5*b*, there is some tendency for grain growth to stop at former grain boundaries but this tendency is much more marked in the killed steel, Fig 5*c* and 5*d*. This grain boundary restraint, together with the relatively slow rate of nucleation in this type of killed steel, apparently is responsible for its relatively coarse elongated grain structure after recrystallization. The presence of thorium oxide particles, similarly, has been shown to restrain grain growth and result in an elongated grain structure in recrystallized tungsten wire.[2,3] It still is not clear, however, why grain growth of aluminum killed steel is restrained more effectively in the thickness direction than it is in the lengthwise or crosswise direction of the sheet, as it must be if such restraint is responsible for the plate-like shape of the recrystallized grains. This effect suggests the possible presence in the steel of fine particles distributed more or less in layers parallel to the sheet surface.

As expected, increased cold reduction reduces the time required for complete recrystallization of either of the steels represented in Fig 2 and increases their hardness as fully recrystallized. This increased hardness is due to a finer grain size, as illustrated in Fig 6. For the same amount of prior cold reduction the killed steel, with its elongated grain structure, is softer, and its grain size coarser, than the equiaxed rimmed steel.

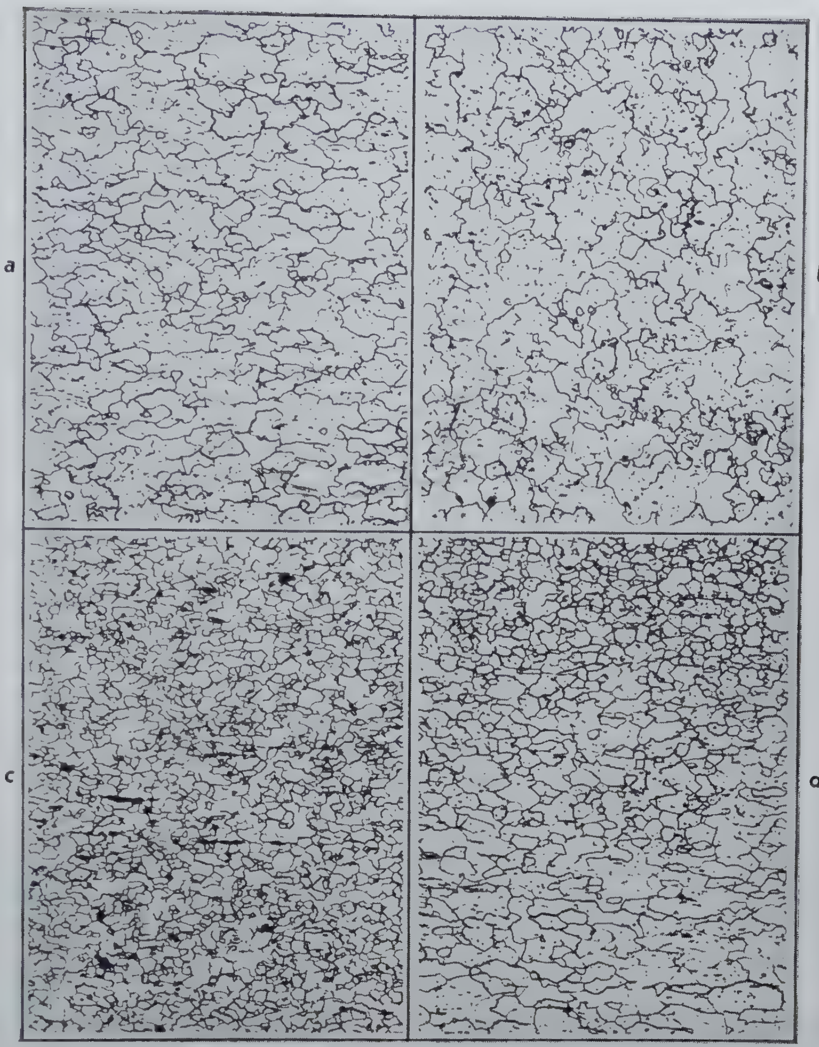


FIG 1—Types of microstructure observed in aluminum killed steel after cold reduction and box annealing. 100 ×. Nital etch.

*a.* Typical elongated grains, conventional longitudinal section. *b.* Same specimen as *a* but section parallel to sheet surface. *c.* Equiaxed ferrite grains, longitudinal section. *d.* Equiaxed grains (top) and elongated grains in a single specimen.

## Effect of Temperature of Isothermal Recrystallization

The effect of temperature on rate of isothermal recrystallization was investigated, again using rimmed steel *A* and killed steel *B* of Table 1, each cold reduced 40 pct. For rimmed steel, Fig 7*a*, the shape of the recrystallization curve is not altered appreciably by change in temperature, although as would be expected the time required for a comparable amount of recrystallization is less the higher the temperature. Fig 7*a* shows that over the range 1000 to 1100°F, hardness of this steel after complete recrystallization is nearly independent of recrystallization temperature; final grain size, likewise, was found to be about the same for all.

The effect of temperature, in the range 1050 to 1200°F, on isothermal recrystallization of the aluminum killed steel is shown in Fig 7*b*. At each temperature investigated, the amount of recrystallization remains nearly constant over an appreciable period of time, resulting in a "shelf" in the recrystallization curve. The amount of recrystallization corresponding to this shelf increases, and the time to attain it decreases, with increased temperature. Duration of the shelf period also is shorter the higher the temperature. Hardness of this steel as fully recrystallized increases as the recrystalliza-

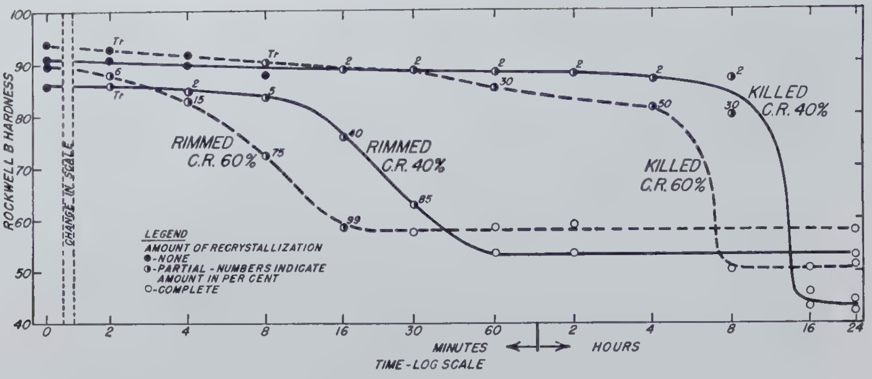


FIG 2—Rate of isothermal recrystallization of rimmed steel A and aluminum killed steel B at 1050°F after 40 pct and after 60 pct cold reduction.

tion temperature is raised, Fig 7*b*, the higher hardness resulting from a finer, more equiaxed grain structure, as shown in Fig 8.

The aluminum killed grade thus differs from rimmed steel in requiring a longer time for complete recrystallization at comparable temperature, in having a "shelf" in its isothermal recrystallization curve, and in becoming finer grained as the recrystallization temperature is raised.

## Effect of Treatment Prior to Cold Reduction

Early in this investigation, it was discovered that normalizing the aluminum killed steel at about 1700°F after hot rolling, but before cold reduction, resulted in an equiaxed rather than an elongated grain structure after subsequent cold reduction and box annealing. This observation led to a more extensive study of the influence of such heating prior to cold reduction on final grain structure.

Specimens of steel *B* of Table 1, in the form of hot rolled strip 0.075 in. thick, were heated at each of a series of temperatures for 20 min. then air cooled. Another set was prepared in which the heating time was 2 hr. The specimens of both sets were then cold reduced 40 pct in thickness, using a small laboratory rolling mill, after which they were annealed 16 hr at 1275°F in a protective atmosphere. The laboratory annealing cycle simulated commercial box annealing practice, both heating and cooling rates being in the range of 20–50°F per hour. Microstructure, after cold reduction and annealing, of the specimens heated for 20 min. or 2 hr prior to cold reduction is shown in Fig 9. Holding 2 hr at 1000°F had little effect on the final structure, but 2 hr at 1100°F resulted in a mixed elongated and equiaxed structure, whereas holding 2 hr at 1200°F or above resulted in a final structure that is almost entirely equiaxed.

The change in grain structure, as box annealed, from elongated to equiaxed is accompanied by an appreciable increase in hardness of the annealed material. Fig 10 shows the relationship between temperature of heating, prior to cold reduction, and hardness of the subsequently cold reduced and box annealed product. The two curves in Fig 10 are for 20 min. and 2 hr at temperature in the initial treatment, and show that the longer time lowers the temperature range over which the change in final structure and hardness takes place. Fig 11 shows that prior heating for as long as 24 hr at 800 or 1000°F had no appreciable effect on final hardness whereas 2 hr at 1200°F or 5–10 min. at 1300°F increased hardness of the cold-rolled, annealed material to a maximum; this maximum hardness corresponds to a substantially equiaxed grain structure. Fig 10 and 11 thus demonstrate that the change in

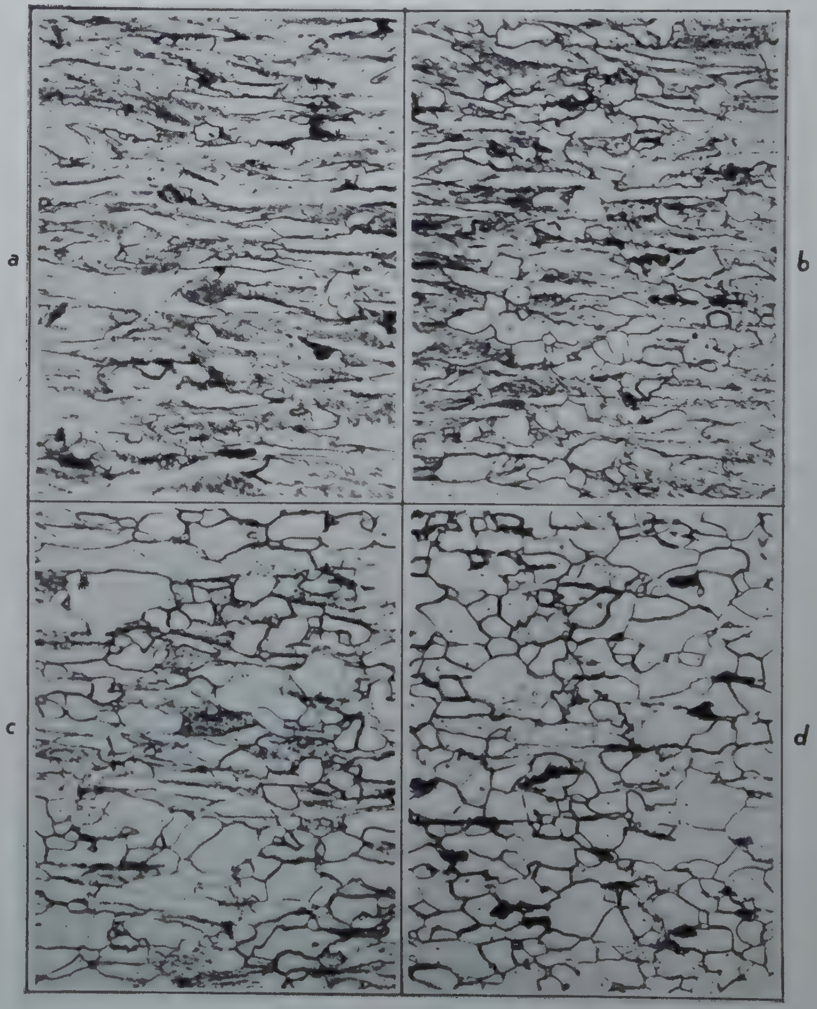


FIG 3—Progress of isothermal recrystallization of rimmed steel A at 1050°F after 60 pct cold reduction. 500 ×. Nital etch.
*a.* 2 min. *b.* 4 min. *c.* 8 min. *d.* 12 min.

structure and hardness as annealed is dependent upon both time and temperature of the treatment prior to cold reduction, the time required being shorter the higher the temperature, within the range investigated.

The foregoing observations indicate that slow rather than rapid cooling of this aluminum killed steel directly following hot rolling should yield an equiaxed grain structure after subsequent cold reduction and annealing. This was confirmed by cooling samples at three rates after heating to 2150°F and hot rolling from 0.15 to 0.085 in. (43 pct reduction) in a single pass through a small laboratory rolling mill. The three rates of cooling were obtained by: (1) quenching in oil, (2) cooling in air, and (3) placing in a furnace at 1500°F immediately after hot rolling and cooling with the furnace (1 hr to cool from 1500 to 1350°F). After cold rolling 40 pct and box annealing 16 hr at 1275°F, grain structure of the previously oil quenched or air cooled samples was elongated, whereas that of the slow-cooled sample was equiaxed, as shown in Fig 12.

The foregoing experiments demonstrate that the thermal history between hot rolling and cold reduction is an important factor in determining whether the grain structure of this aluminum killed steel, when recrystallized after cold reduction, will be elongated or equiaxed. Either slow cooling from the temperature at which hot rolling is finished, or suitably reheating more rapidly-cooled strip leads to the formation of equiaxed grains in the final annealed product similar to those commonly found in box annealed rimmed steel. This raised the question whether the recrystallization of "equiaxed" aluminum killed steel may not also resemble that of rimmed steel, rather than being much more sluggish as is characteristic of the elongated-grain type (Fig 2 and 7). To answer this question, suitable samples cold rolled 40 pct were recrystallized isothermally at 1050°F, with results shown in Fig 13 and 14.

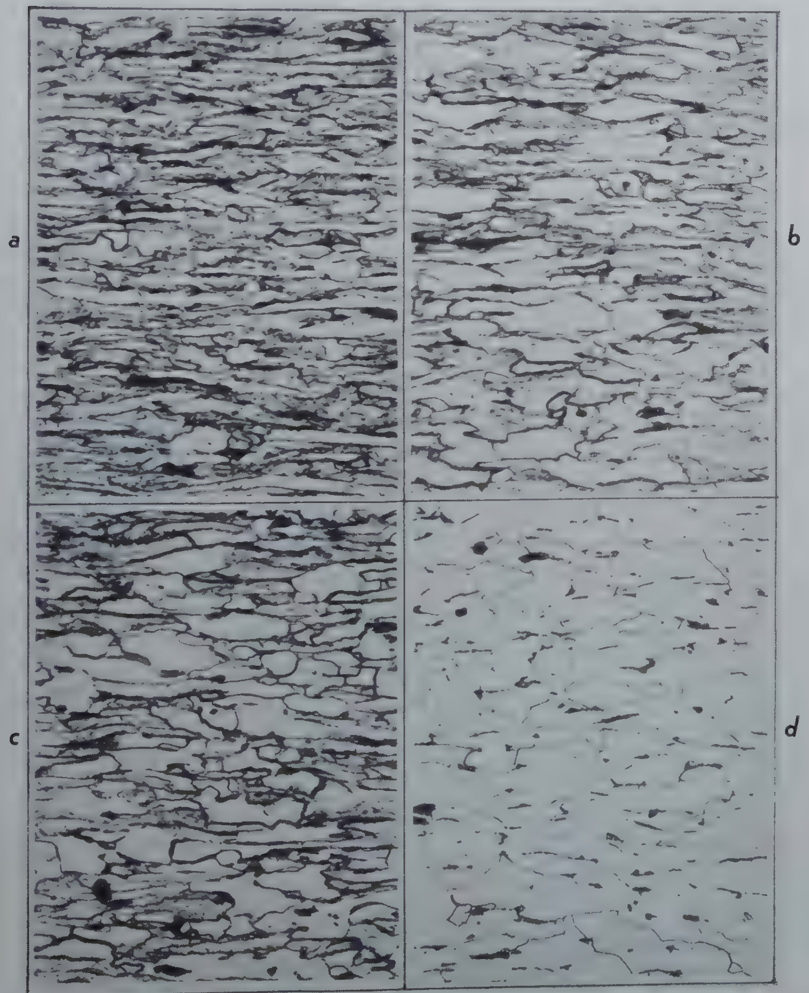


FIG 4—Progress of isothermal recrystallization of aluminum killed steel B at 1050°F after 60 pct cold reduction. 500 ×. Nital etch.
*a.* 8 min. *b.* 1 hr. *c.* 4 hr. *d.* 5 hr.

To determine the effect of cooling rate on isothermal recrystallization at 1050°F, Fig 13, specimens of steel *D*, Table 1, were hot rolled in regular production, and cooled rapidly to about 1330°F; a portion was then cooled slowly below this temperature, whereas another portion was cooled much more rapidly. The rapidly cooled portion, subsequently cold rolled and completely recrystallized at 1050°F, had an elongated grain structure, and, as shown in Fig 13, its recrystallization curve exhibits the "shelf" characteristic of such material. The more slowly cooled strip when cold reduced and recrystallized had an equiaxed grain structure like that of rimmed steel; the recrystallization curves for this and for the rimmed steel in Fig 13 likewise are similar in shape, although the killed steel recrystallized somewhat more slowly. Fig 14 shows the effect of reheating to 1300°F after hot rolling on isothermal recrystallization after cold reduction, the steel being the same aluminum killed steel as in Fig 2. The effect of this treatment on recrystallization is the same as that of slowly cooling the strip directly after hot rolling; recrystallization proceeds more rapidly, and in more continuous fashion than when the strip is cooled rapidly after hot rolling and is not reheated. Final recrystallized grain structure of this steel previously heated at 1300°F before cold reduction was equiaxed, whereas without such treatment it was elongated.

Fig 13 and 14 thus demonstrate that when the treatment of aluminum killed steel prior to cold reduction is such that the final recrystallized grain structure is equiaxed rather than elongated it recrystallizes more readily and its recrystallization curve exhibits no "shelf," thus resembling rimmed steel in these respects.

## Recrystallization on Continuous Heating

In regular commercial practice cold rolled strip or sheet is box annealed in the approximate temperature range 1200–1350°F after cold reduction. Rate of heating is necessarily rather slow, because a large amount of metal is annealed in each batch, and partial or complete recrystallization occurs during the heating period. Since the structure of aluminum killed deep drawing

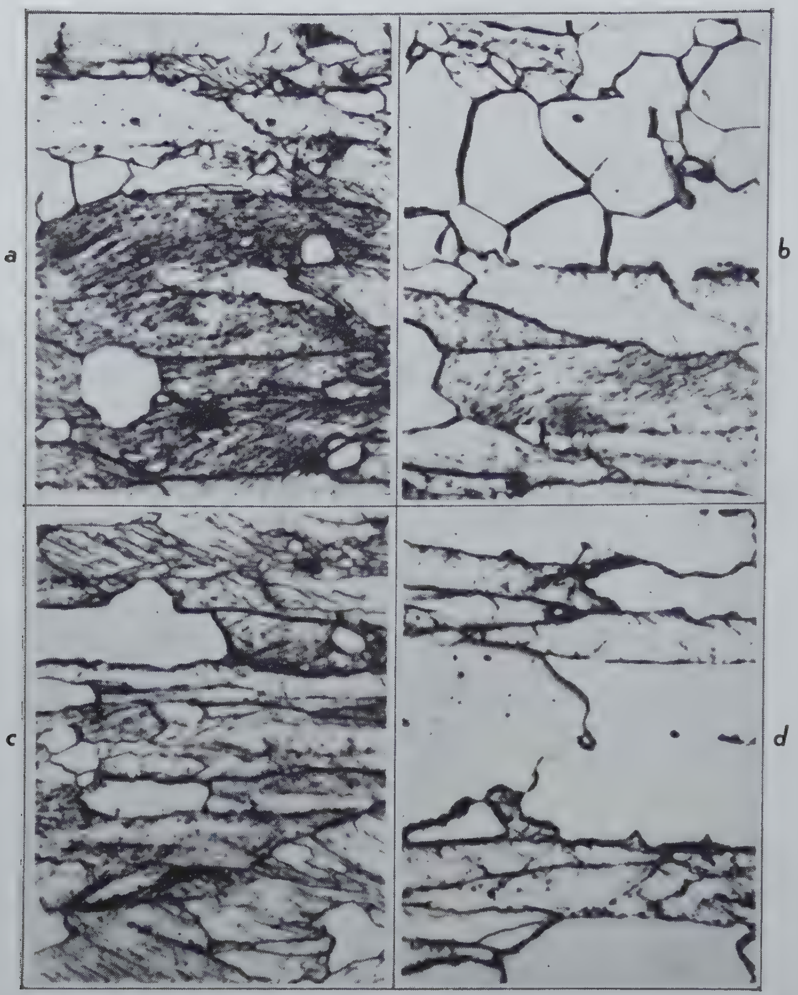


FIG 5—Comparison of microstructure of rimmed and aluminum killed steels partially recrystallized isothermally at 1050°F after 60 pct cold reduction. 2000 ×. Nital etch.

*a.* Rimmed steel, 2 min. *b.* Rimmed steel, 8 min. *c.* Killed steel, 8 min. *d.* Killed steel, 4 hr.

sheet varies with the temperature at which it is recrystallized (Fig 8) it was decided to investigate the recrystallization of this steel on continuous heating at several rates, and the effect of such variation in heating rate on the final grain structure.

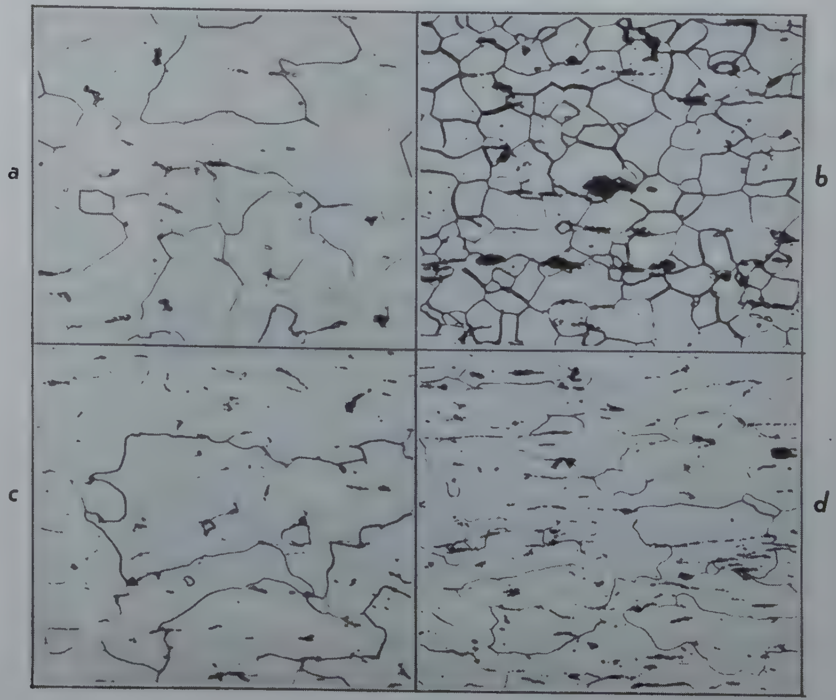
For this purpose, Steels, *E*, *F*, *G*, and *H* of Table 1 were used; *E* was cold reduced 40 pct in the laboratory, the others were cold rolled in regular production. Several specimens of each were heated at a controlled constant rate of 20, 50, or 300°F per hr in lead, starting at 700°F. As each selected temperature was reached, a specimen was removed from the lead and air cooled.

Results of these tests for Steels *F*, *G* and *H* are shown in Fig 15. When heated continuously at 20°F per hr, Fig 15*a*, steel *F* started to recrystallize at about 1050°F but had not recrystallized completely on reaching 1150°F, the highest temperature investigated. The hardness curve for Steel *G* follows closely that for Steel *F*; however, *G* was completely recrystallized on reaching 1100°F. Steel *H* differs from the others in that it recrystallized over a considerably lower temperature range. Structure of all three steels after recrystallization was elongated.

As would be expected, the effect of increasing the heating rate, Fig 15*b* and 15*c*, is to raise the recrystallization temperature range. The curve for Steel *G* heated at 300°F per hr exhibits a "shelf" not apparent at slower heating rates; the curve for Steel *H* also has a

FIG 6—Effect of amount of prior cold reduction on structure of rimmed and aluminum killed steels after complete recrystallization at 1050°F. 500 ×. Nital etch.

*a.* Rimmed steel cold red. 40 pct. *b.* Rimmed steel cold red. 60 pct. *c.* Aluminum killed steel cold red. 40 pct. *d.* Aluminum killed steel cold red. 60 pct. Slightly reduced in reproduction.



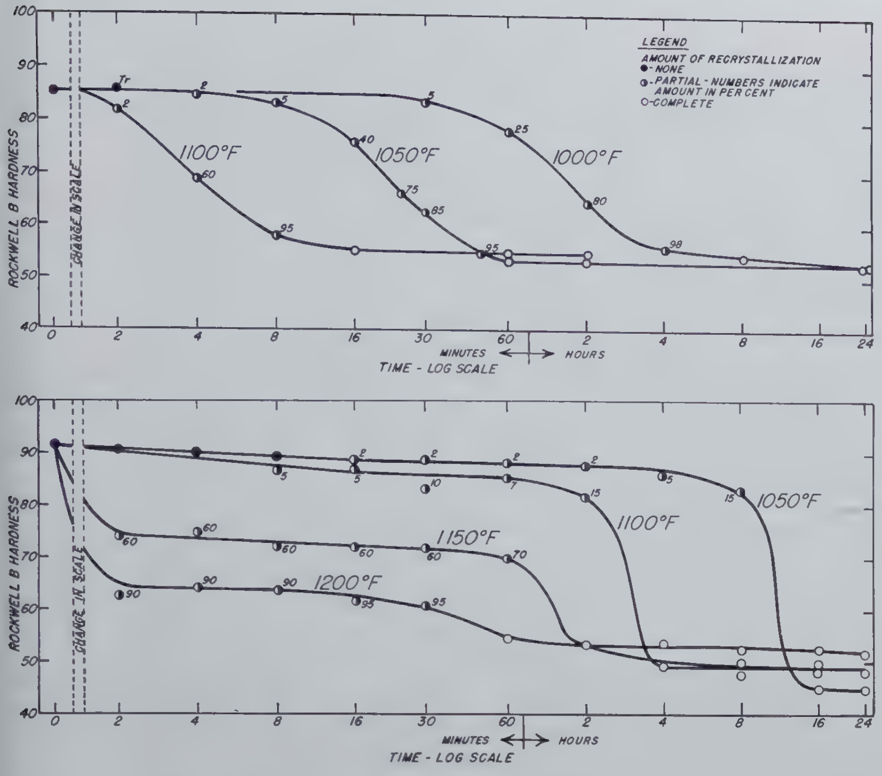


FIG 7—(*a.* Above). Effect of temperature on rate of isothermal recrystallization of rimmed steel A and aluminum killed steel B (*b.* Below). Cold reduced 40 pct.

"shelf" at somewhat lower hardness. This latter steel is unusual in that its recrystallized grain structure becomes much finer and more nearly equiaxed when the rate of heating is raised from 50 to 300°F per hr. No such effect was found in the other steels over the range of heating rate investigated.

Differences among these steels do not seem to be related to their composition, as given in Table 1, but are believed to be due to differences in prior processing, as discussed below, although this is not known with certainty.

Recrystallization on continuous heating, like isothermal recrystallization, is influenced by treatment of the steel prior to cold reduction. Fig 16 shows the effect of heating Steel *E*, Table 1, 20 min. at 1300°F before cold rolling as compared to the same steel hot rolled only before cold reduction. The 1300°F treatment prior to cold reduction lowers the recrystallization temperature range for each of the three heating rates and results in an equiaxed rather than an elongated recrystallized grain structure. From this, it appears likely that Steel *H*, Fig 15, was cooled after hot rolling in such a manner that its tendency toward an elongated grain structure, on recrystallization, was only partly destroyed rather than completely destroyed as was that of Steel *E* when heated to 1300°F after hot rolling.

## Summary

The results of this investigation show that the recrystallization of rimmed steel *at constant temperature* proceeds in a regular and continuous manner, once it starts, as is already well known. On the other hand, the recrystallization of aluminum killed steel of the elongated-grain type takes place in three rather distinct stages: (1) an initial period resembling the start of recrystallization in rimmed steel; (2) a second period during which recrystallization proceeds very slowly; and (3), comparatively rapid recrystallization of the remaining unrecrystallized portion. The length of time required for complete recrystallization is ordinarily much greater for the aluminum killed steel than for rimmed steel at a comparable temperature. Except at the very start, the recrystallized grains in this type of killed steel are definitely elongated

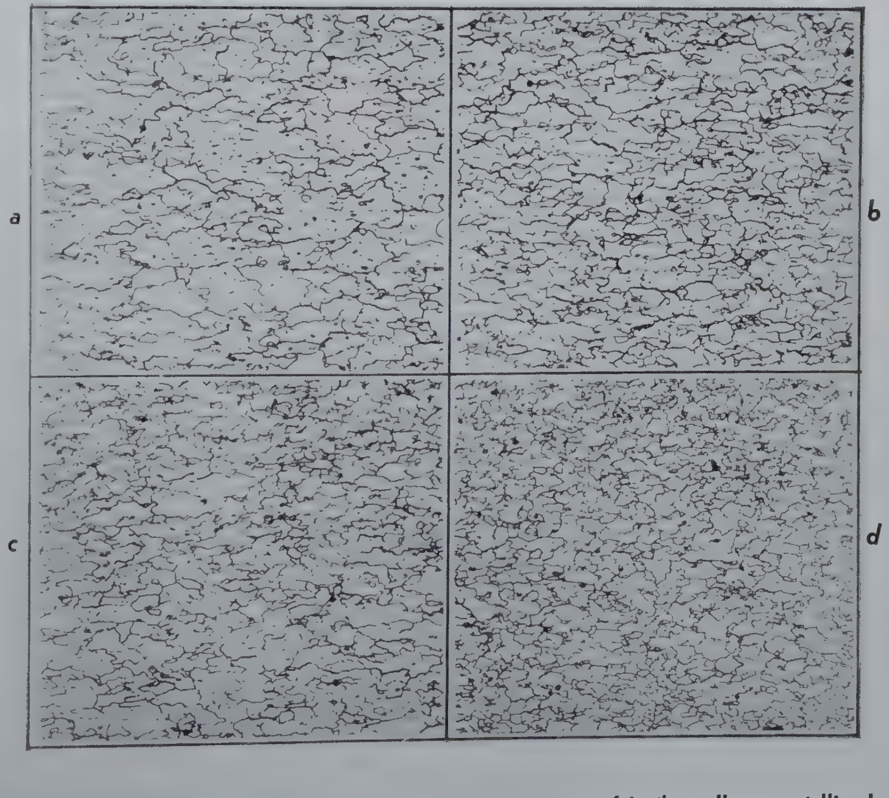


FIG 8—Effect of recrystallization temperature on structure of isothermally recrystallized aluminum killed steel cold reduced 40 pct. 100 ×. Nital etch.
*a.* 1050°F. *b.* 1100°F. *c.* 1150°F. *d.* 1200°F.

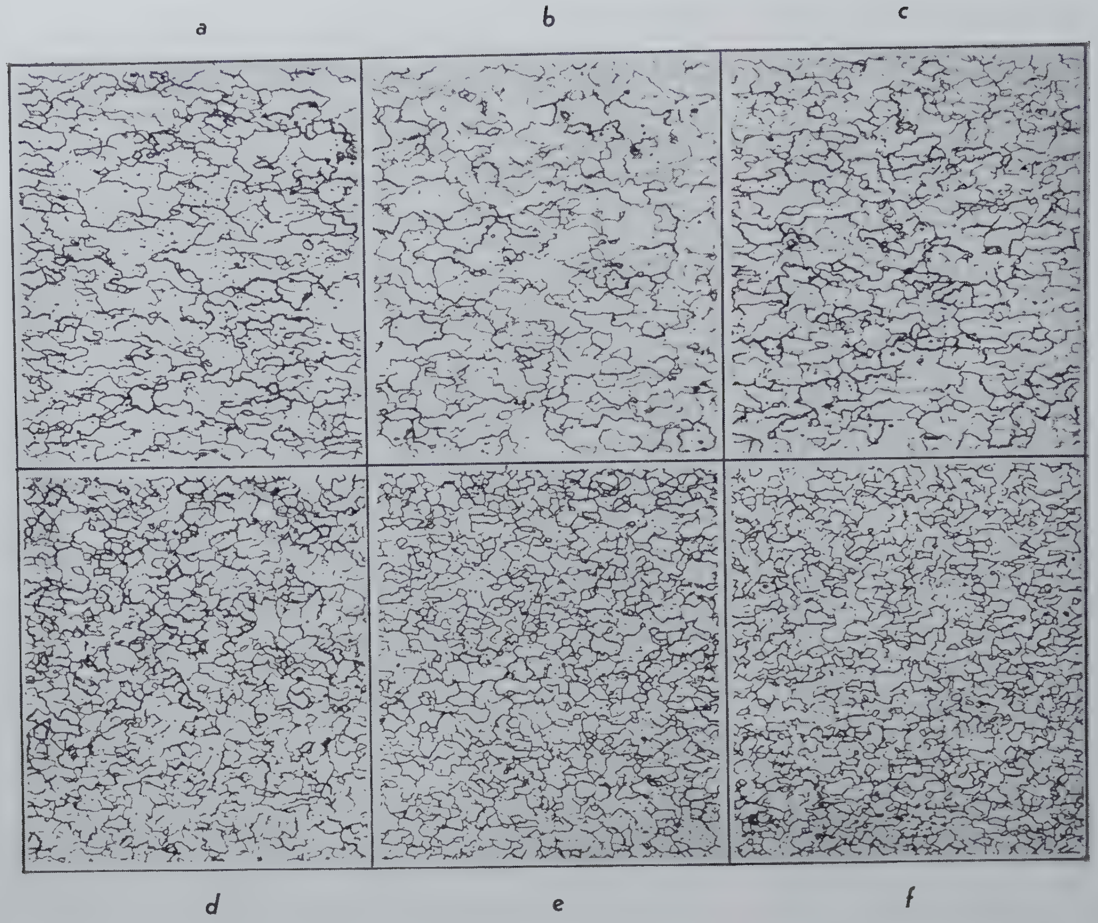


FIG 9—Effect of prior heating on grain structure of aluminum killed steel B annealed 16 hr at 1275°F after 40 pct cold reduction. 100 ×. Nital etch.

Treatment before cold reduction: *a.* None, hot rolled only. *b.* 2 hr at 1000°F. *c.* 2 hr at 1100°F. *d.* 2 hr at 1200°F. *e.* 20 min. at 1300°F. *f.* 20 min. at 1650°F.

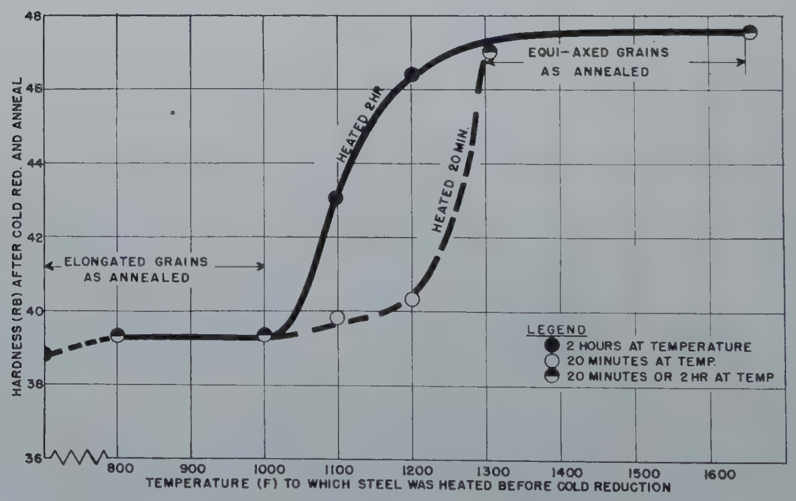


FIG 10—Effect of heating aluminum killed steel B for 20 min. or 2 hr at indicated temperature on hardness after subsequent cold reduction (40 pct) and box anneal (16 hr at 1275°F).

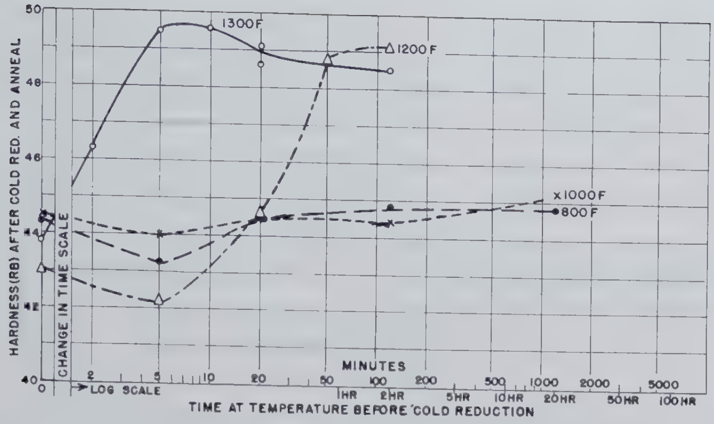


FIG 11—Effect of time at indicated temperatures on hardness of aluminum killed steel subsequently cold reduced 40 pct and box annealed (16 hr at 1275°F).

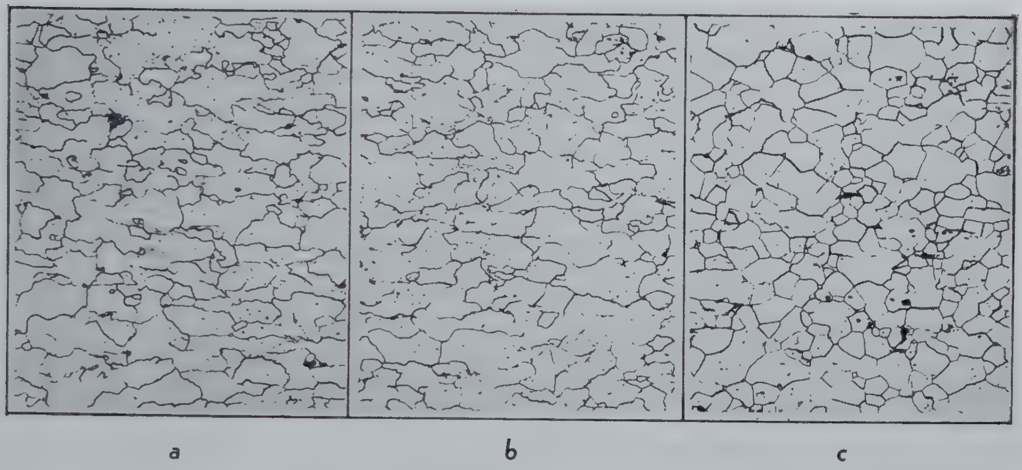


FIG 12—Effect of method of cooling, following hot rolling, on grain structure of aluminum killed steel after subsequent reduction (40 pct) and box annealing. 100 ×. Nital etch.

*a.* 0.085 in. thick hot rolled strip oil quenched. *b.* 0.085 in. thick hot rolled strip air cooled. *c.* 0.085 in. thick hot rolled strip placed in furnace at 1500° F and furnace cooled.

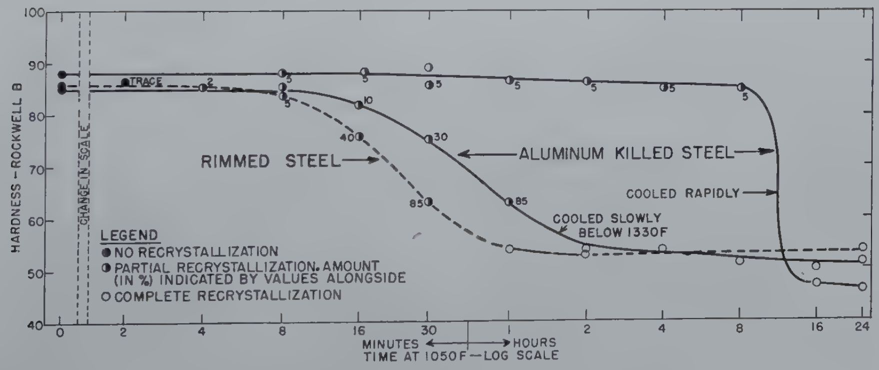


FIG 13—Effect of cooling rate after hot rolling on isothermal recrystallization of aluminum killed steel D at 1050°F, following 40 pct cold reduction. Curve for rimmed steel cold reduced 40 pct reproduced from Fig 2 for comparison.

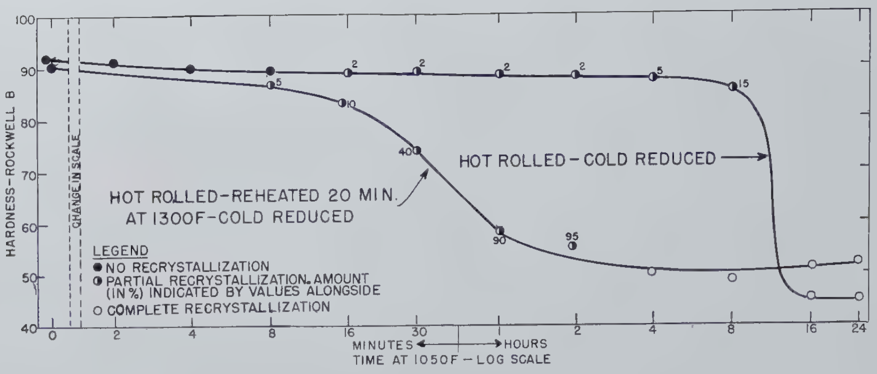


FIG 14—Effect of heating aluminum killed steel *B* at 1300°F on subsequent recrystallization at 1050°F following 40 pct cold reduction.

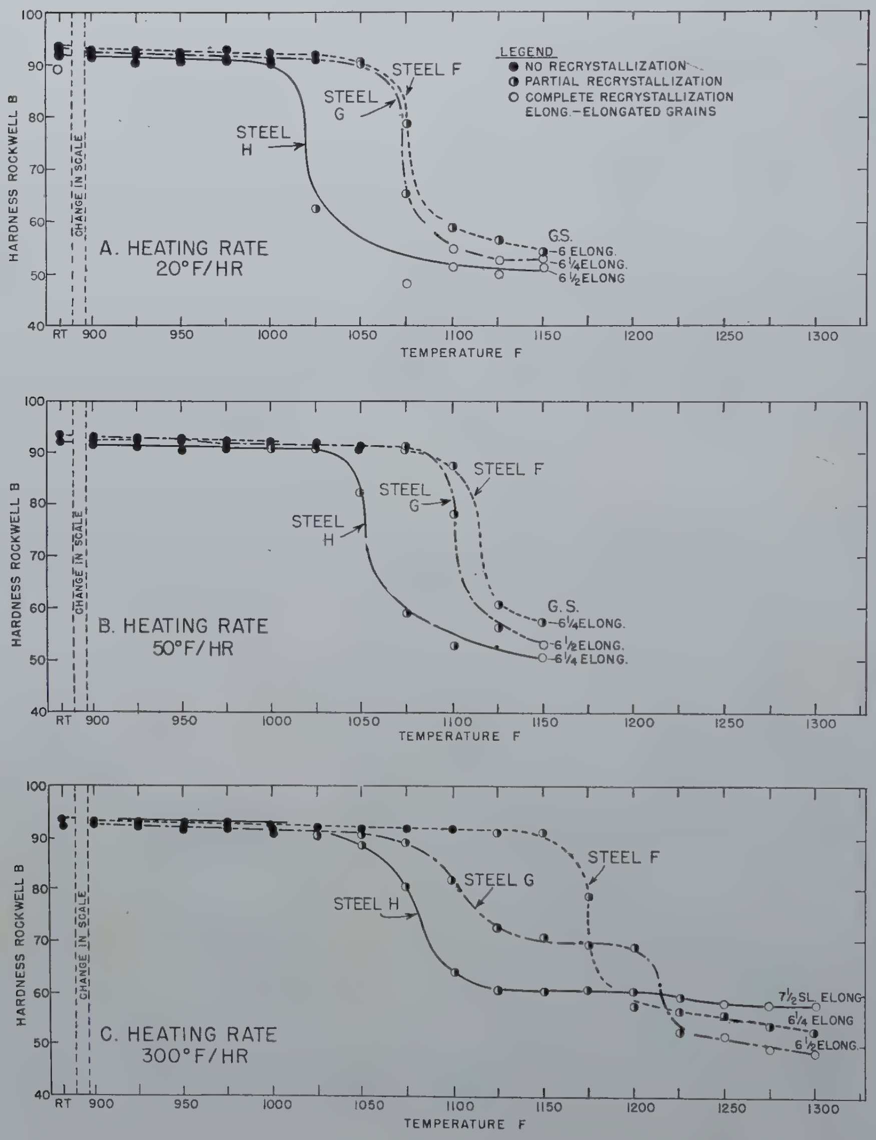


FIG 15—Effect of heating rate on recrystallization of aluminum killed steel during continuous heating after 40 pct cold reduction.

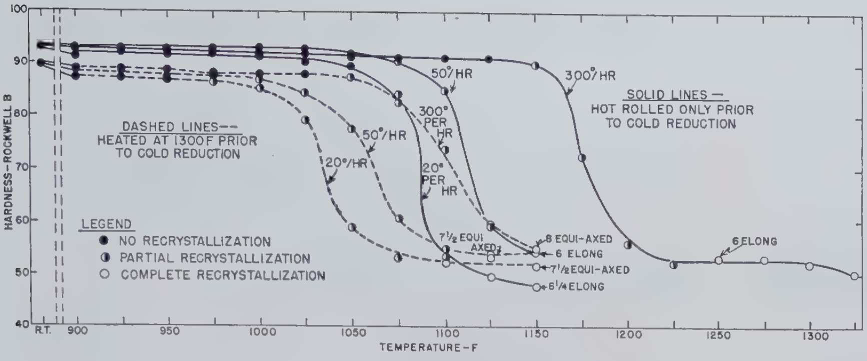


FIG 16—Effect of prior treatment at 1300°F on recrystallization of aluminum killed steel E when heated continuously at 20, 50 or 300°F per hr after 40 pct cold reduction.

whereas the grains in rimmed steel are predominantly equiaxed.

An increase in temperature accelerates the recrystallization of rimmed steel but does not essentially change the *shape* of the isothermal recrystallization curve; final grain size and hardness are changed to a minor extent, if at all. In the isothermal recrystallization of aluminum killed steel, increase in temperature increases the amount of recrystallization which takes place in the initial stage, shortens the second and third stages but does not eliminate them, and makes the grain size finer and more nearly equiaxed.

The isothermal recrystallization pattern of subsequently cold reduced aluminum killed sheet steel may be made to approach that of rimmed steel by slowly cooling the hot rolled strip or by reheating it for a sufficient length of time to a temperature of approximately 1200°F or above, then cooling at any convenient rate; the recrystallized grain size is then comparatively fine and the grains tend to be equiaxed.

The recrystallization temperature range on continuous heating of aluminum killed steel is raised by increasing the rate of heating and in some instances the grain structure becomes finer and more equiaxed. Treatments prior to cold reduction that result in an equiaxed structure on subsequent recrystallization lower the recrystallization temperature range on continuous heating.

It was observed that when killed steel recrystallizes to an elongated-grain structure the first new grains to form are widely scattered and initially may be more or less equiaxed; as they grow they have considerable difficulty in crossing the cold-worked grain boundaries and consequently become elongated in shape like the original deformed grains. Recrystallization gradually progresses to adjacent cold-worked grains so that the final recrystallized grains are, to some extent, built up of elongated units which correspond to the original deformed grains. When recrystallization takes place at a comparatively low temperature, the number of locations or nuclei where new grains start is limited and the final grain size is coarse; but as the recrystallization temperature is increased, more nuclei form, the final grain size becomes finer, and the grains tend to be less elongated. In rimmed steel, or in killed steel which recrystallizes to give an equiaxed structure, the number of nuclei increases rapidly as recrystallization progresses and becomes much greater than in killed steel of the elongated-grain type at the same temperature; resistance to growth across the old grain boundaries is also less; the result is an equiaxed grain structure and, generally, a finer grain size. The formation of coarse, elongated, recrystallized grains appears, therefore, to be due to some factor which reduces the number of effective recrystallization nuclei and also restrains grain growth. The precise nature of this restraining influence has not been established.

## Acknowledgments

This investigation was suggested by Dr. John Johnston, then Director of Research, United States Steel Corporation. The assistance of various operating personnel, particularly at Gary Sheet and Tin Mill and Irwin Works of Carnegie Illinois Steel Corporation, in supplying materials and that of Gary Works Laboratory in making the hot rolling tests is greatly appreciated, as are the suggestions of associates in both the Research Laboratory and operating companies. Messrs. H. M. Evers and L. B. Haberman helped with portions of the experimental work.

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# Precipitation Phenomena in the Solid Solutions of Nitrogen and Carbon in Alpha Iron below the Eutectoid Temperature*

L. J. DIJKSTRA†

## Introduction

DURING the past several years an extensive study has been made of the internal friction of iron containing carbon or nitrogen in solid solution.[1,2,3,4,5] It has been found that a sharp peak is observed in a plot of the internal friction vs. temperature of measurement. With a frequency of about one cycle per second, this peak occurs at 20°C for N and 36°C for C. The physical origin of this anomalous internal friction was traced by Snoek[1] to the local tetragonal symmetry of the interstitial positions in body centered cubic (bcc) iron. A change in stress induces a change in the equilibrium distribution of the interstitial atoms among the three types of interstitial positions, the three types corresponding to the three directions along which the tetragonal axis may lie. It is the continual striving of the interstitial atoms to maintain an equilibrium distribution that gives rise to a phase lag between strain and stress during oscillation, and hence, to internal friction. A similar type of internal friction has been observed in the bcc lattice of tantalum containing in interstitial solid solution C, N or O[6].

The theory of this anomalous internal friction leads to the prediction that its magnitude is strictly proportional to the concentration of either the carbon or the nitrogen in solid solution, provided the concentrations are small. This prediction has been verified[3] for the range of solubilities obtainable in alpha iron. This proportionality provides us with a new tool for the study of nitrogen and carbon in alpha iron. It thus enables one directly to follow the precipitation of either of these solute atoms from solid solution and also directly to measure their solubility as a function of temperature. A preliminary study of precipitation using this method has already been presented by the author.[3] The purpose of this paper is to present more extensive observations upon the precipitation of N and C in alpha iron, as well as to present observations upon the solubility of N and C in alpha iron which, at least in the lower temperature range, are believed more accurate than those previously obtained by other methods.

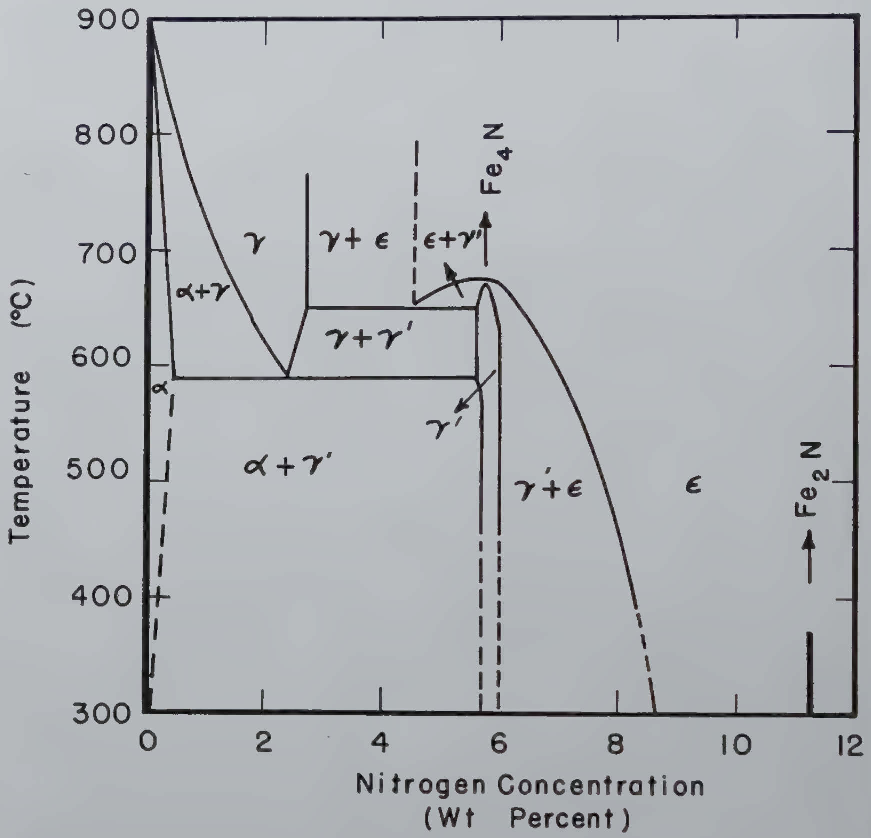

FIG 1—(Above) Fe-N equilibrium diagram (after Lehrer-Eisenhut and Kaupp[2]).

The interpretation of the observations upon precipitation involves the use of the appropriate equilibrium diagrams. For ease of future reference in this paper the equilibrium diagrams for the Fe-N and Fe-C systems are accordingly reproduced as Fig 1 and 2, respectively.

## Experimental Procedure

The specimens were made of Westinghouse Puron iron and consisted of wires 0.025 in. in diam and about 1 ft long. By a wet hydrogen treatment the specimens were purified of C and N. In

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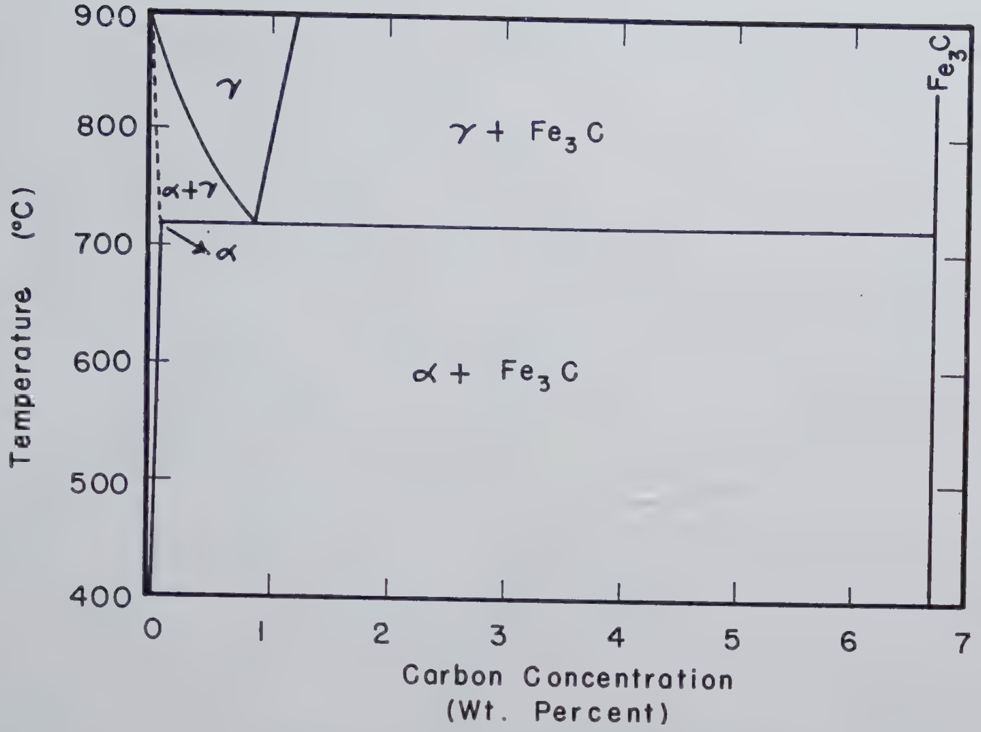

FIG 2—(Below) Fe-C equilibrium diagram.

order to make internal friction measurements the wires were used as the suspension element in a torsional pendulum system with a period of vibration of about 1 sec. The damping is determined by measuring the logarithmic decrement of the free torsional vibration using a very small vibrational amplitude. The apparatus is very similar to that previously described by T. S. Kê.[4] The wire was surrounded by a furnace to enable us to vary the temperature, which variation is necessary in locating the maximum in the internal friction. All data have been corrected for a relatively small background damping of $Q^{-1} = 0.001$. Here, as in the following, we shall take as the quantitative measure of internal friction the quantity $Q^{-1}$, which is [5] $\pi^{-1}$ times the logarithmic decrement, ($\frac{1}{2}\pi$) times the specific damping capacity. A calibration of the value of $Q^{-1}$ at the maximum of the internal friction peak, $Q_{max}^{-1}$, vs. resistivity, and a comparison of Köster's[7] resistivity vs. concentration curves, has shown that $Q_{max}^{-1}$ is equal, within the 10 pct accuracy of the measurements, to the wt pct concentration in the case of both carbon and nitrogen in solid solution.

The N was introduced in the standard way by annealing the specimen in a mixture of $H_2$ and 3–5 pct (by volume) of $NH_3$ at 580° for some hours, until the wire was homogeneously loaded with N. The homogeneous distribution throughout the specimens could be checked microscopically after precipitation. By varying the partial pressure of the $NH_3$ in the mixture the amount of N introduced could be controlled. After quenching from 580°C by immersion into cold water or by exposure to a compressed air stream all the N was retained in supersaturated solid solution, as was verified by varying the quenching rate.

The C was introduced in a similar way by annealing the sample at 700°C in a mixture of $H_2$ and benzene, followed by quenching in cold water.

The introduction of N and C by this method has the disadvantage that atomic H is generated which will readily enter into the Fe-lattice. It is well known that the absorption of H affects the mechanical properties of Fe. Most of the H will diffuse out again by heating in a neutral atmosphere. Iron which was pickled in acid, and which had thereby taken up a large amount of H, did not show any contribution by H to the internal friction in the temperature region between −40 and 100°C. How far the specimen may have been damaged by the H, for example, by causing small rifts and thus affecting the precipitation phenomena, we do know, but assume it is not serious.

The general procedure was as follows. After being quenched from the nitriding or carburizing temperature to room temperature, the specimens were tempered at a definite temperature. In order to determine the C or N content still present in solid solution after increasing periods of tempering, the specimens had to be quenched to room temperature to measure $Q_{max}^{-1}$, which took about 5 min. The drop in $Q_{max}^{-1}$ due to aging during this short interval was generally negligible. Sometimes the time intervals of tempering were rather short (15 sec), necessitating rapid heating to the tempering temperature. For this purpose hydrogen was used as the tempering atmosphere at moderate temperatures (heating time was 3 sec in $H_2$, 30 sec in air). At temperatures above 400°C we used He since the N and C content of the wire decreased noticeably at these temperatures in a hydrogen atmosphere.

It was found possible to use a single specimen in a whole series of measurements. After aging or tempering, during which the N or C had been rejected partially or completely from solid solution, the original state of complete solid solution was reestablished by what we shall call a re-solution heat treatment. This re-solution heat treatment consisted of a 580°C (or 720°C for C) anneal for about 1 sec and subsequent quenching. This was repeated more than 50 times without any change being noticed in the initial value of

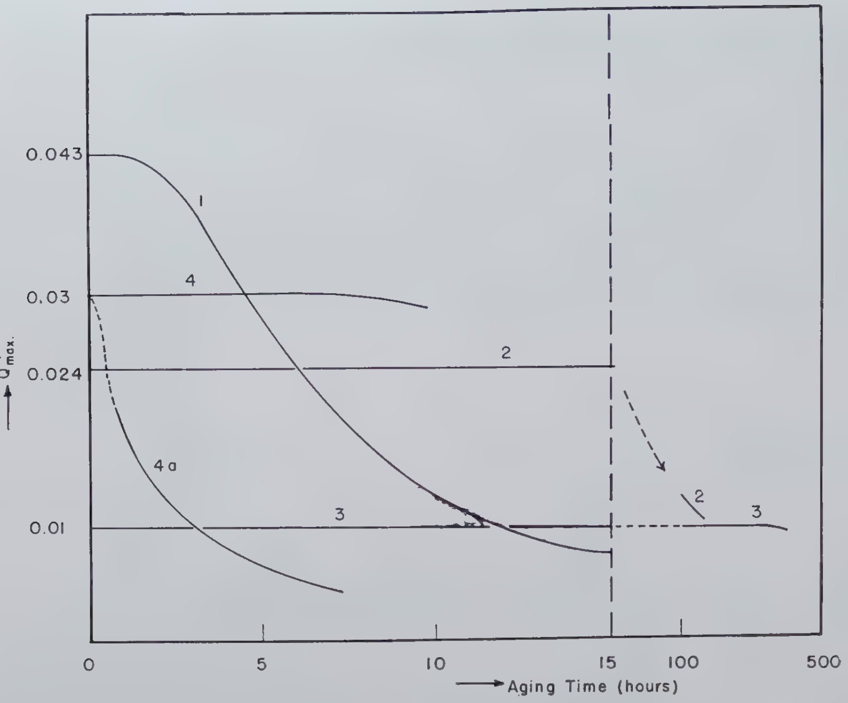

**FIG 3—Typical room temperature aging curves; 1,2,3,4 as quenched; 4*a* same as 4, except for cold work following quench.**

$Q_{max}^{-1}$. Even after extended tempering times at higher temperatures no more than 5 sec were required to eliminate the tempering effects. After this re-solution heat treatment one could start again and find the measurements reproduced quite satisfactorily.

## Internal Friction Measurements

We first confine ourselves to the case of nitrogen in solid solution. A brief discussion of carbon in solid solution will be given at the end of this section.

Fig 3 shows typical aging curves for four specimens. They were all slowly cooled from 950°C and afterwards loaded with different amounts of N as indicated by the initial $Q_{max}^{-1}$. After a re-solution heat treatment specimen 4 has been cold worked to 48 pct reduction in area. The corresponding aging-curve is denoted as 4*a*. These curves show clearly the large influence of the initial concentration of N and of the state of cold work upon the rate at which N is rejected from solid solution. To investigate the effect of temperature these two factors should be kept constant; this was assured by the re-solution heat treatment.

In Fig 4*a* and 4*b* are reproduced a typical set of tempering curves for a series of temperatures ranging from 0 to 500°C. The curves for the temperatures 250, 275, and 300°C are only partially drawn in Fig 4*a*; the complete tempering curves are given in Fig 4*b*. All the measurements were made on the same specimen, which, before nitriding, had been slowly cooled from 950°C. The various measured initial values of $Q_{max}^{-1}$, of about 0.042, corresponding to a total N content of about 0.04 pct, show how nicely they are reproduced by the re-solution treatment. The time scale is a logarithmic one. We wish to point out the following:

1. If a linear time scale is used instead of a logarithmic one, a number of curves, especially those for the lower temperatures, still show the very small initial slope which rapidly increases. This may mean that some nucleation stage is involved, usually called incubation or induction period.

2. After the initial drop (*dash*) the curves approach a horizontal section. This indicates that a stationary state, which can be temporary, is approached in which the N concentration in solid solution has decreased to a certain constant value. This residual value is zero within the limits of measurements, at temperatures below 100°C, but increases rapidly for higher temperatures.

3. For more extended tempering times at intermediate temperatures a second drop (*solid line*) starts and continues until a final equilibrium state is reached, which final state proved to be permanent even for very extended tempering times. The tempering times for temperatures below 250°C have been too short to observe the second drop, though there can hardly be any doubt that it must also be present below this temperature.

At temperatures above 250°C there seems to be no opportunity for the intermediate, "stationary" state to develop completely, due to the interference with the second drop. Above 300°C the first drop has completely disappeared and only the second process remains. The final residual solubility rapidly increases with temperature and at 500°C no decrease of $Q_{max}^{-1}$ on tempering could be observed for this N content.

4. If we further compare the dashed tempering curves for different temperatures in Fig 4*a*, then we see there is a shift to the left with increasing temperature. This shift is almost parallel as long as the curves drop to a low value. Above 250°C this shift to the left reverses into a shift to the right, towards longer tempering times. The solid curves show about the same behavior.

Considering the dashed curves, we shall define a half time value $t_{1/2}$ as being the time necessary to reach the $Q_{max}^{-1}$ midway between the initial and residual value. In Fig 5 log $t_{1/2}$ has been plotted against $1/T$ in the region 0 to 200°C. The dots and circles refer to two different successive runs through the whole temperature region. The curves seem rather straight, but show a somewhat sudden bend at 100 and just below 20°C. This bend was reproducible and seems to indicate that the phenomenon is rather complicated.

5. The specimen was then annealed for ½ hr in wet $H_2$ at 700°C and afterwards for some hours in dry $H_2$ at 500°C to assure a homogeneous distribution of the N. After this treatment the $Q_{max}^{-1}$ was 0.023, corresponding to a total N content of about 0.02 pct. The tempering curves for this concentration in Fig 6 show the same general behavior as those in Fig 4. The dashed curves, as well as the solid one, seem to approach the same equilibrium values of $Q_{max}^{-1}$ as the curves in Fig 4. (The $Q_{max}^{-1}$ scale is different in Fig 4 and 6.) The only obvious effects of the concentration difference are, first, a large increase in $t_{1/2}$ below 100°C so that the sudden bend in the curve at 100°C in Fig 5 has disappeared, and secondly, a lowering of the temperature at which

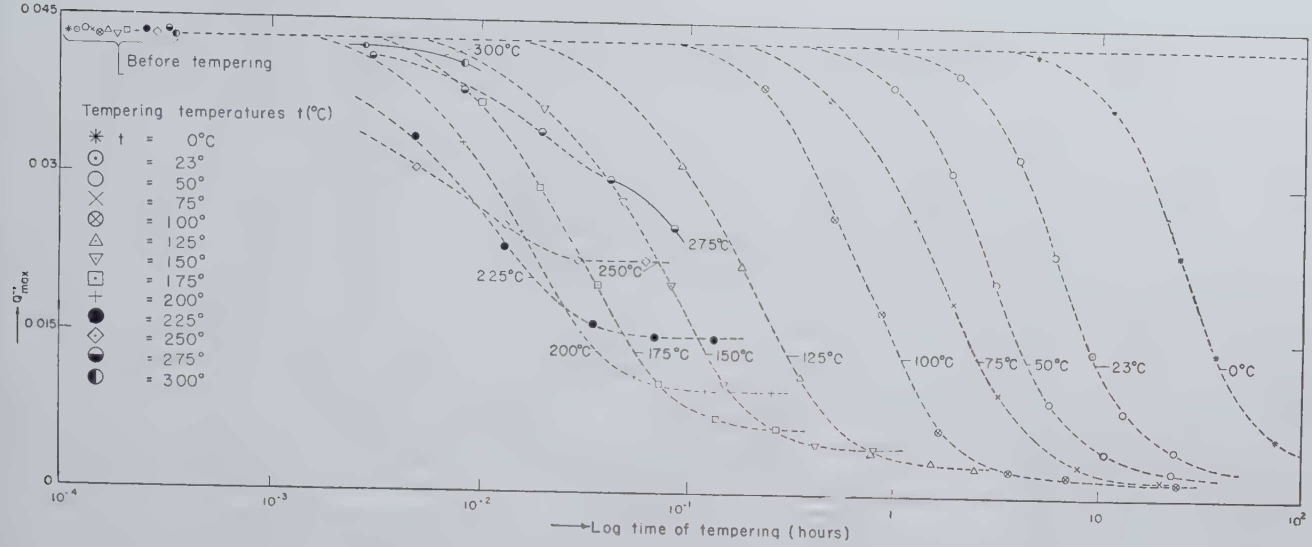

**FIG 4*a*—Effect of aging at low temperatures (*R.T.*—300°C). All measurements are at room temperatures following indicated aging. Initial concentration of nitrogen is 0.043 wt. pct.**

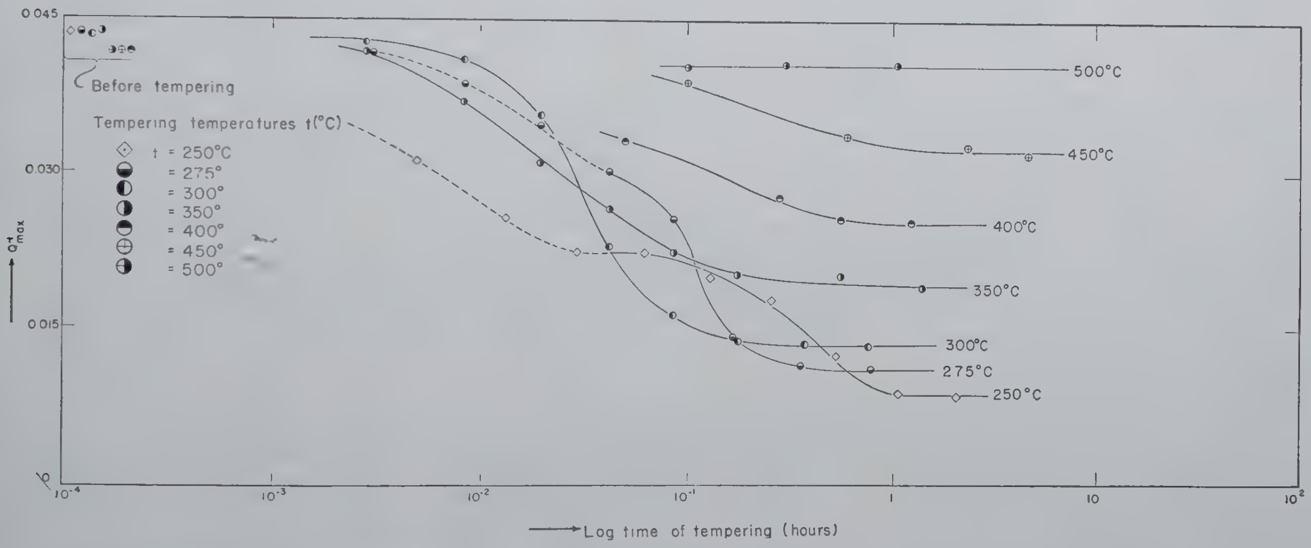

**FIG 4*b*—Effect of aging at high temperatures (250–500°C). Dashed lines: intermediate precipitation. Full lines: precipitation of Fe$_4$N.**

the first drop disappears. The solid curves for 250°C in Fig 4*b* and 6 are almost identical, although in Fig 4*b* a large first drop has preceded it.

We may briefly summarize the above observations as follows: At intermediate temperatures the rejection of N from the supersaturated solid solution takes place according to two different successive processes. By lowering the temperature the earlier reaction will predominate; by raising the temperature, the later one. The fact that the completion of the earlier rejection process does not seem a necessary condition for the beginning of the second one (in a certain temperature region we even observe that the temperature dependence of the rate of both processes has a different sign), suggests that the two processes occur independently of each other with rates having a different temperature dependence.

It seems most natural to relate each quasi-stationary or stationary state in the tempering curves to the existence of some Fe-N phase, whatever it may be. The height of a horizontal part represents the solubility of N in α-iron in equilibrium with the corresponding Fe-N phase. According to the preceding paragraph, it appears, then, that the observed Fe-N phases are independent of one another, that the earlier phase is not an intermediate or transitional state of the final phase.

In the case of a perfect solid solution the solubility $[c]_{sat}$ must satisfy a relation of the type

$$\left(\frac{\partial \ln [c]_{sat}}{\partial T}\right)_p = \frac{\Delta H}{RT^2}$$

or

$$\ln [c]_{sat} = -\frac{\Delta H}{RT} + \text{const.}$$

ΔH is the heat of solution per gram mol. of the precipitated phase. In Fig 9 the values of $[c]_{sat}$ as given by the horizontal parts in Fig 4, and in a number of curves which we did not reproduce, have been plotted on a logarithmic scale versus $\frac{1}{T}$ both for the intermediate phase (*curve* 1) and for the final phase (*curve* 2), which we assume to be Fe$_4$N. The values

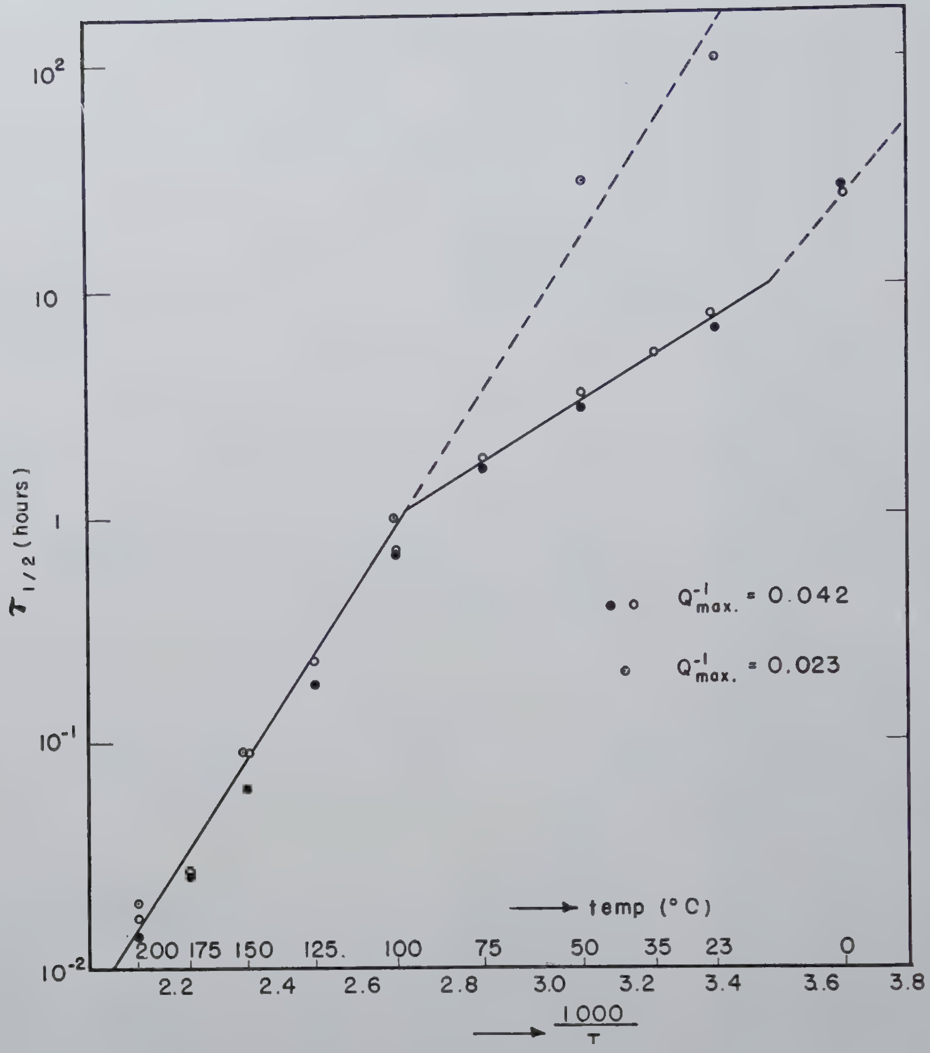

FIG 5—Temperature dependence of time required for precipitation to be one-half complete for two initial concentrations.

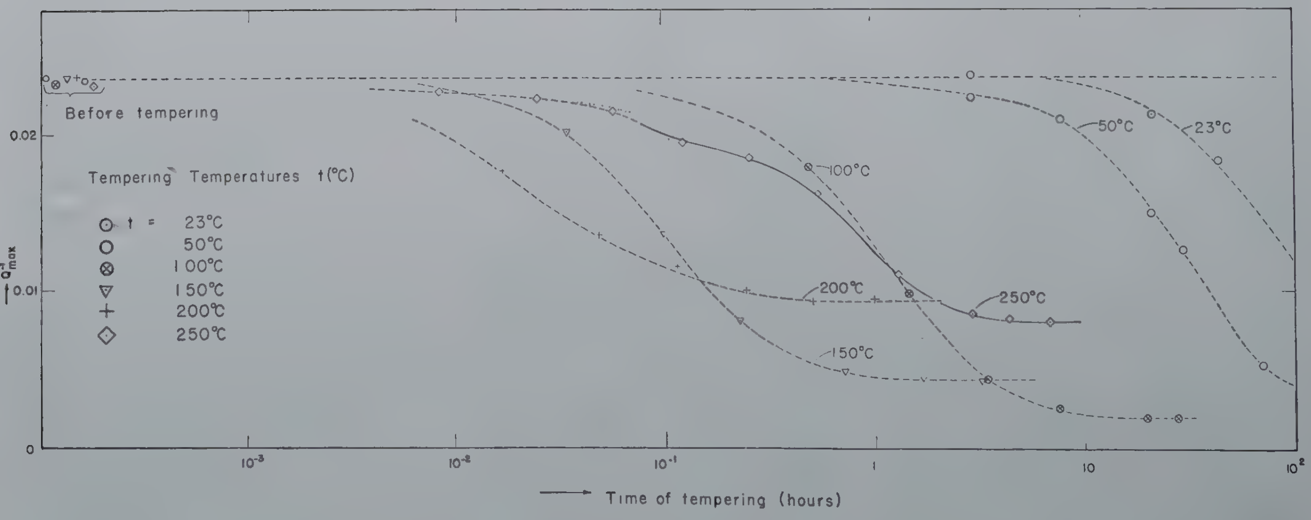

FIG 6—Effect of aging at low temperatures (*R.T.*—300°C). All measurements are at room temperatures following indicated aging. Comparison with Fig 4*a* illustrates effect of initial concentration upon rate of precipitation.

for $Fe_4N$ from Fig 4*a* for the lower temperature are probably too high because the tempering times have been too short to reach real equilibrium. At the highest temperatures we met with the difficulty that the N content seemed to decrease during tempering, even using He as a gas atmosphere. Therefore we followed another way and nitrided the specimen at 575°C for a sufficiently long time in $H_2 + NH_3$ mixtures of increasing $NH_3$ content until no further increase in $Q_{max}^{-1}$ was observed. This final value of $Q_{max}^{-1}$ gives us the solubility for $Fe_4N$ at 575°C. It would take us too long to do the same for all the lower temperatures. Therefore we simply annealed this loaded specimen at the desired lower temperatures in adequately rich $H_2 + NH_3$ mixtures, during which $Q_{max}^{-1}$ dropped until the equilibrium value was reached. These values are given by the black dots in Fig 9 and seem to us to be the best ones. From the slope of the curve we calculate that ΔH for both precipitates is of the order of 8,000 cal per mol. An extrapolation of our data to 590°C, the eutectoid temperature for the Fe-N system, gives for the maximum solubility about 0.10 pct.

It is possible to get higher concentrations of N into solid solution in the following way: by annealing in $H_2 + NH_3$ mixtures above the eutectoid temperature some f.c.c. γ-phase is formed (see Fig 1) which by rapid quenching down to room temperatures apparently transforms into the bcc α-phase. During this quenching no precipitation takes place, though there must have been some diffusion of N between adjacent interstices in order to obtain the cubic phase and not a martensitic structure. In this way we have observed values for $Q_{max}^{-1}$ of 0.12. These highly supersaturate solutions are extremely unstable and precipitate at room temperature in about 5 min.

The precipitation of C from a supersaturated solid solution has been investigated along lines similar to that for N. The value of $Q_{max}^{-1}$ in the freshly quenched state was 0.02, which corresponds roughly to a carbon content of 0.02 pct by weight. The tempering curves did not show any observable sign of a double stage character at any temperature. The half time value for well annealed material was about 2-3 hr at 100°C, about 2 min. at 200°C, and about 10 sec at 300°C. For higher temperatures precipitation was so rapid that we were able to observe only the final equilibrium values.

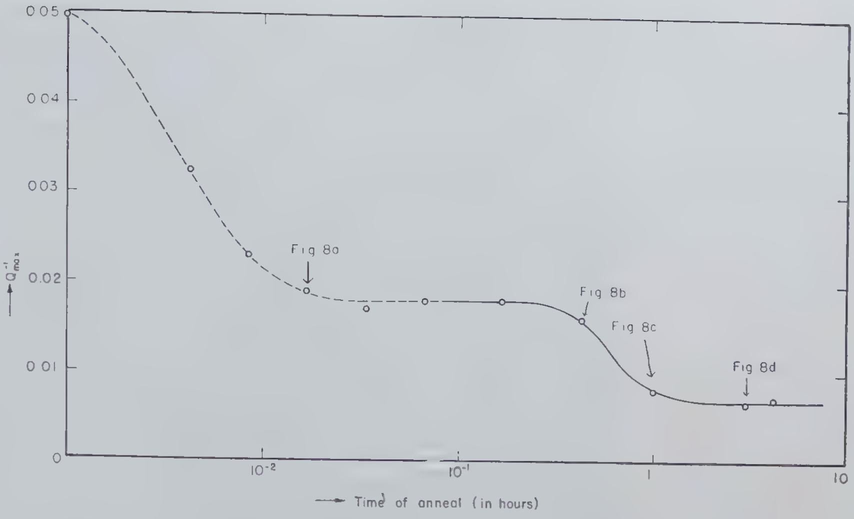

FIG 7—Aging history of specimens whose micrographs are given in Fig 8.

*Table 1 . . . Solubility of Carbon in Alpha Iron in Equilibrium with $Fe_3C$.*

| *t* (°C) | 250° | 400° | 450° | 500° | 550° | 600° | 650° | 700° | 710° |
|---|---|---|---|---|---|---|---|---|---|
| $Q_{max}^{-1} \simeq [c]_{sat}$ | 0.001 | 0.002 | 0.003 | 0.004 | 0.007 | 0.01 | 0.012 | 0.016 | 0.020 |

These data are plotted in Fig 9 and from the slope of Curve 3 we calculate for the heat of solution of $Fe_3C$ in α-iron about 10,000 cal per mol.

The above determined values of the solubility of C in α-iron with respect to $Fe_3C$ are only about one-half the values reported by Köster.[7] The extrapolated value at the eutectoid temperature of 723°C obtained from the above data is, however, in excellent agreement with the value of 0.025 wt pct given by Smith[9] from an extrapolation of his higher temperature data on the equilibrium of C in α-iron with C in γ-iron.

## Results of Microscopic Investigation

A specimen purified of C by wet $H_2$ treatment was loaded with N. The initial value of $Q_{max}^{-1}$ was 0.049. The tempering curve for 250°C is shown in Fig 7. After a re-solution heat treatment the tempering treatment at 250°C was repeated. Micrographs of the various stages during tempering were made on small samples cut from the quenched specimen after increasing tempering periods. Some of them with tempering times indicated by arrows in Fig 7, and which were most characteristic, have been reproduced in Fig 8 (*a*—*d*). No micrographs were taken for other tempering temperatures. The magnification was 500×; the etchant was picral. The big dark spots are oxide impurities. After some seconds the micrographs reveal the very early stages of some visible precipitation process. After 1 min., when the first equilibrium state in Fig 7 is reached, these early stages have developed into a highly dispersed but well-defined structure shown in Fig 8*a*. The measured distance between the dark etched N-rich regions is about $10^{-4}$ cm. This value is consistent with the calculated diffusion distance $X$ according to $X = \sqrt{Dt}$, in which $t$ is tempering time in seconds and the atomic diffusion coefficient[2] $D$ is $5.2 \times 10^{-4} \epsilon^{-20,000/RT}$ cm²sec⁻¹. From the initial concentration of about 0.05 pct N we now calculate easily that the thickness of the platelets precipitated must be of the order of 10Å, assuming that each observed platelet is not a series of smaller parallel platelets. That they nevertheless show up so markedly in the micrograph must be an etching effect which is probably due to the fact that a large region around the precipitate is in a state of high internal strain caused by the precipitate itself.

Though Fig 7 shows that no further precipitation from the α-Fe phase takes place for tempering times between 1 and 30 min., successive micrographs during this period demonstrate that the structure has not reached a steady state. The distance between the platelets gradually increases, presumably due to a coagulation process. After 30 min. the regular geometrical pattern

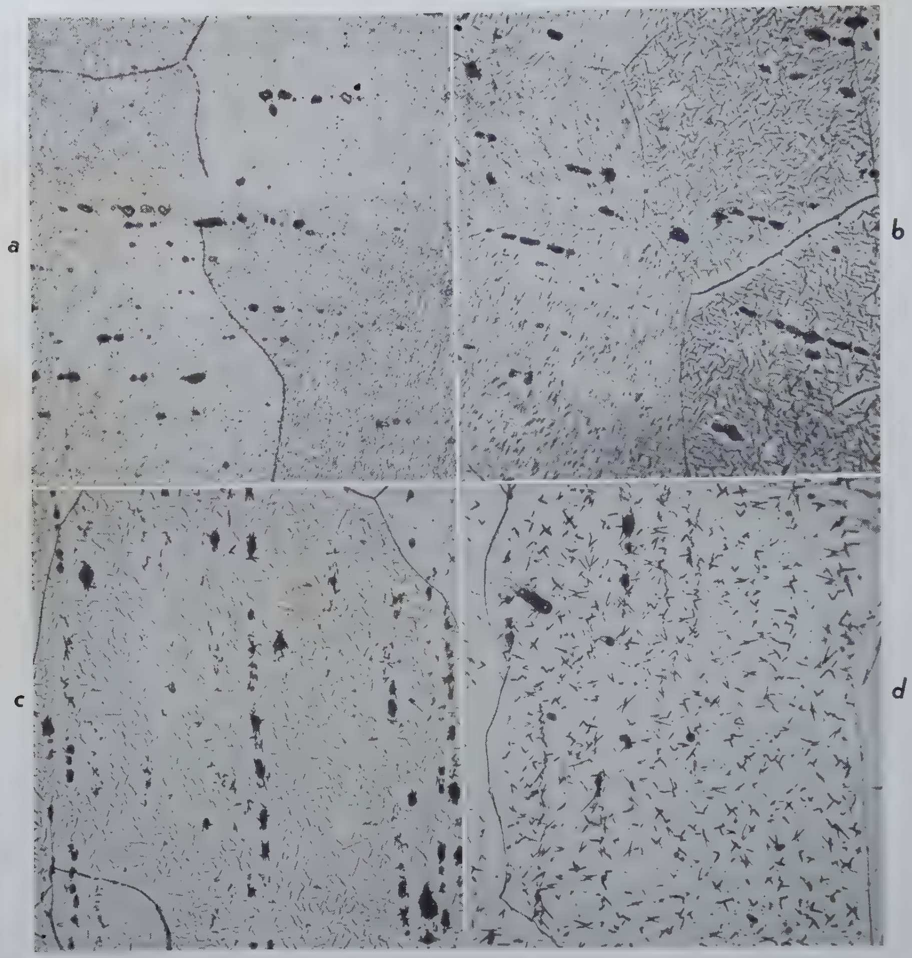

FIG 8—Illustration of two types of precipitates: *a* and *b*, intermediate phase; *c*, intermediate and $Fe_4N$ phase; *d*, $Fe_4N$ phase. Aging history given in Fig 7. × 500. Reduced approximately one third in reproduction.

of Fig 8*b* is obtained. Similar platelike structures arranged along definite crystal planes (the so-called Widmanstätten structures) are quite common in precipitation phenomena[10] though their explanation is still unsatisfactory. Very often the dark etched regions consist of a series of mostly parallel, close, rather short plates, which cause the wavering character of the etching marks.

The pattern in Fig 8*b* generally shows no more than 3 different orientations of the plates, and from simple geometrical considerations it is clear that these plates of a precipitated Fe-N phase must be arranged parallel to the (100) planes of the bcc iron matrix. Very often the polishing plane itself is parallel to a (100) plane and then the Widmanstätten pattern shows only 2 orientations at right angles, as in some of the crystal grains in Fig 8*b*. Moreover, in this case the polishing plane sometimes cuts just across a plate in its own plane and we see round etched areas which are vaguely visible in the rectangular spaces between the dark lines; they do not show up well in the micrographs. They prove that the precipitate is indeed plate-shaped and not needlelike. The thickness of these plates must be of the order of 50Å. Micrographs made of these tempered specimens after a one second anneal at 600°C followed by quenching (re-solution heat treatment) did not show any trace of precipitate in accordance with the internal friction measurements.

At this time and even earlier a new precipitate (indicated by II to distinguish it from the former precipitate I) suddenly develops here and there. It is easily observed because it etches much darker with picral than I. Precipitate II almost directly shows the well known plate structure of the iron nitride $Fe_4N$. Fig 8*c* corresponds to a tempering time of 40 min. During the second drop of the curve in Fig 7 the micrographs show that the number and size of the $Fe_4N$ plates increase, while phase I is fading away, especially in the vicinity of the $Fe_4N$ plates.

After 1 hr phase I is still visible, although only faintly; after 3 hr of tempering we distinguish only the $Fe_4N$ plates (Fig 8*d*). The Widmanstätten patterns of phase I and $Fe_4N$ are quite different. The large number of different orientations of the "nitride needles" in Fig 8*d* indicates that the lattice planes of the matrix along which the plates of the phase $Fe_4N$ are arranged must be of a higher order. According to the literature[11] $Fe_4N$ precipitates in plates along the (210) plane of the bcc matrix lattice, which generally causes 12 different orientations of the needles in the micrograph.

We were not able to detect any clearly pronounced relationship between the two precipitates. The $Fe_4N$ plates seem to originate from nuclei inside or very close to the plates of phase I as well as somewhere else. The fact that the phases I and II precipitate on quite different lattice planes of the matrix is reason to suppose that there exists no definite relationship and that phase I is not an intermediate transition state of phase II, as for instance is observed in the precipitation of Cu and Ag in Al.[12] We thus see that this microscopic work confirms the conclusions in section 3 regarding the independence of the nucleation of phase II from the presence of phase I.

As mentioned in the preceding section, the curves of internal friction vs. time of tempering did not suggest the presence of an intermediate precipitate in the Fe-C system. Micrographs showing successive stages during tempering at 250°C revealed only small round dots of precipitate which coagulated somewhat during extended tempering times.

## Kinetics of Precipitation

Certain observations reported above which, at least on the surface, appear anomalous may be readily understood when cognizance is taken of the standard nucleation theory. This theory has been discussed in great detail by Volmer,[13] so only the results of the theory need be herein reproduced.

According to the standard nucleation theory the rate of formation of new nuclei, N, is given by the product of two factors each of which depends upon temperature in a characteristic manner. Thus

$$N = DS. \qquad [1]$$

The first factor $D$, known as the diffusion factor, decreases rapidly with a decrease in temperature according to the well known equation

$$D \sim e^{-H/RT}, \qquad [2]$$

where $H$ is the heat of activation for the diffusion of the solute atoms. The second factor, $S$, known as the statistical factor, varies with temperature in a quite different manner, namely as

$$S \sim e^{-T_0^3/T(T_e-T)^2}, \qquad [3]$$

where $T_e$ is the equilibrium temperature corresponding to the concentration of the atoms in solid solution. The temperature $T_0$ is a function of the geometry of the nucleus, its interface surface tension with respect to the surrounding matrix, and its heat of solution. The precise manner in which $T_0$ depends upon these parameters need not concern us here. The characteristic manner in which $S$ varies with temperature is determined by the factor $(T_e - T)^2$ in the denominator of the exponent. This exponent insures that the nucleation factor rapidly approaches zero as the temperature $T$ increases towards the equilibrium temperature.

Reference to Fig 4$a$, 4$b$ and 6 shows that as the temperature of tempering is gradually increased above room temperature, the time required for precipitation to be half complete, $t_{1/2}$, at first decreases and then finally rapidly increases at the highest temperatures. According to the above discussion, we are to interpret the lower temperature range, in which $t_{1/2}$ decreases with a rise in temperature, as that range in which the temperature dependence of $D$ dominates. Thus in this temperature range precipitation is limited primarily by the rate of diffusion. On the other hand, the upper temperature range, in which $t_{1/2}$ increases with a rise in temperature, is that range in which the temperature dependence of $S$ dominates. Thus in this temperature range precipitation is limited primarily by the statistical probability of the presence of nuclei of a critical size for spontaneous growth.

Reference to Fig 3 shows that the time for precipitation to be half complete, $t_{1/2}$, is a marked function of the concentration of the solute atoms, rapidly increasing as the concentration is lowered. The same conclusion is reached upon comparing Fig 6 with Fig 4$a$. This marked dependence of $t_{1/2}$ upon initial concentration may be interpreted simply as an increase in $T_e$ with an increase in concentration at a fixed temperature of tempering. Such an increase in $T_e$ may be seen, from Eq 3, to result in an increase in the statistical factor $S$. Thus an increase in initial concentration is seen to affect $S$ in precisely the same manner as a decrease in temperature, namely through an increase in the temperature of undercooling, $(T_e - T)$.

Specimens in which the N precipitates at 23°C in some hours can be stabilized by a preceding tempering treatment at, for example, 250°C. By this we mean that the rate of precipitation at 23°C, after a preceding tempering treatment at 250°C which took out let us say 60 pct of N from solid solution, is much smaller than if the same amount had been rejected from solid solution during preceding aging at 23°C. The explanation must be the different degree of dispersion of the nuclei. It is to be noted that the rate of nucleation is very slow at 23°C after 60 pct of N has been rejected from α-iron.

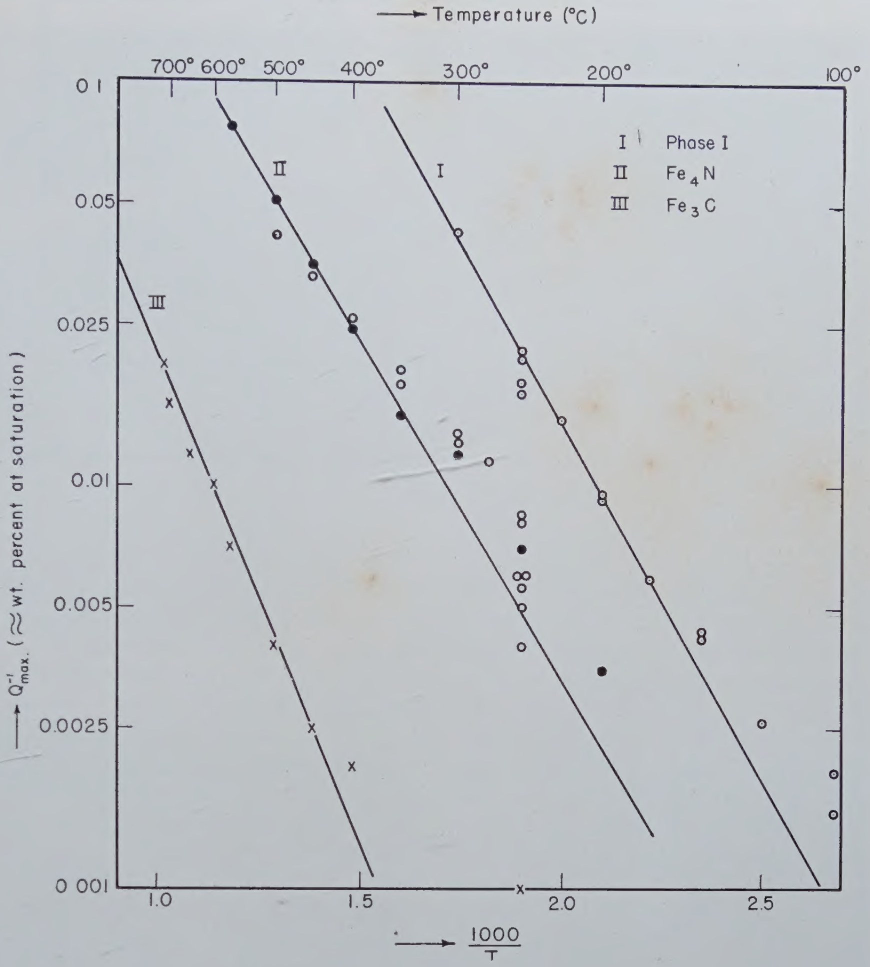

FIG 9—Concentration of N in equilibrium with intermediate phase (Curve I), with $Fe_4N$ (Curve II), and concentration of carbon in equilibrium with $Fe_3C$ (Curve III).

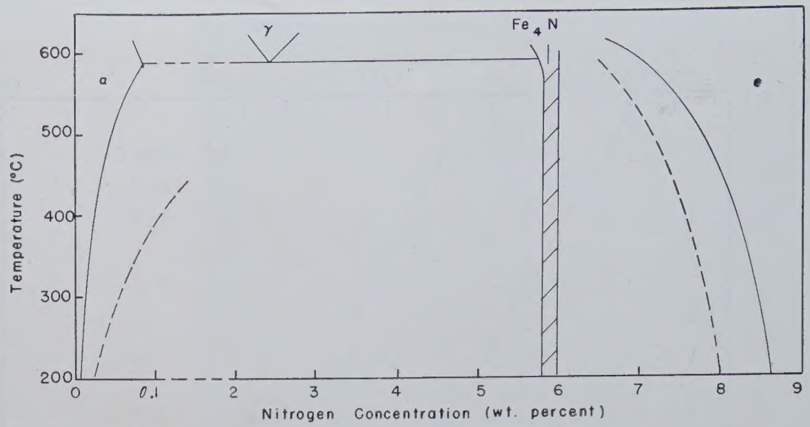

**FIG 10—Equilibrium diagram of Fe-N system including metastable intermediate phase.**

We have yet to interpret the formation of the intermediate phase in the Fe-N system. A tentative interpretation may be arrived at as follows. From our observations it appears that the $Fe_4N$ phase is very difficult to nucleate. The origin of this difficulty is at present unknown. It may possibly reside in an unusually large interface energy between $Fe_4N$ and the surrounding $\alpha$-iron matrix. Reference to Fig 1 shows that if the solid solution of N in $\alpha$-iron is sufficiently undercooled the solution will become supersaturated with respect to the $\epsilon$-phase. This possibility is clarified by the tentative equilibrium diagram of Fig 10. According to this diagram the dashed boundaries of the $\alpha$ and $\epsilon$ phases represent the actual boundaries in the absence of the $Fe_4N$ phase. The dashed boundary of the $\alpha$ phase has been drawn from the data in Fig 9. The dashed boundary of the $\epsilon$ phase has been drawn merely schematically.

The above interpretation of the intermediate phase in the Fe-N system automatically interprets likewise the nonoccurrence of an intermediate phase in the Fe-C system. In the latter system the only stable phase lying to the right of $Fe_3C$ is graphite. This phase actually has a lower solution pressure than does $Fe_3C$. It could not, therefore, form an intermediate phase.

## Effect of Cold Work

It is a well known experimental fact that distorted regions are favorable places for precipitation. The reason was pointed out above. An amount of cold work of 1 to 5 pct reduction in area did not have very much effect on the rate of precipitation of N from supersaturated $\alpha$-iron. Certainly the distances between the distorted regions for this small amount of cold work are too large to affect the precipitation in the specimen as a whole. The effect of 46 pct reduction in area was previously shown in Fig 3. Micrographs of these cold worked specimens being tempered in the region 250–300°C did not show any trace of precipitate. This means that it must be and stay submicroscopically dispersed even at 300°C and that this precipitate modification must be more stable than the usual microscopic $Fe_4N$ plates. A determination of the solubility of N for this precipitate, by the internal friction measurements, indeed proved this to be the case. The solubility at 300°C was about 0.0025 pct, at 400°C about 0.006 pct, while the corresponding values for the $Fe_4N$ plates were respectively 0.012 and 0.025 pct. At higher temperatures the solubility very rapidly increased, partly in an irreversible way due to the fact that the state of cold work is gradually annealed out.

The observed lowering of the solubility of N by plastic deformation is in agreement with the idea advanced by Cottrell that carbon and nitrogen are trapped by dislocations.[14]

## Summary

Precipitation of carbon and of nitrogen from solid solution in alpha-iron has been studied at different tempering temperatures by internal friction measurements.

In the case of nitrogen these measurements suggested the presence of two successive stages in precipitation. This suggestion was then verified by metallographic examinations. In the first stage plates of an unknown precipitate are formed on the (100) planes of the matrix. During the second stage the well known $Fe_4N$ plates are formed. The former unknown phase appears to be less stable than $Fe_4N$, but cannot be considered as a transition state of $Fe_4N$.

The observed rate of precipitation follows the general behavior to be anticipated from the standard theory of diffusion and nucleation, namely low rates at low temperatures (diffusion limitation), low rates at high temperatures near the critical temperature (nucleation limitation) and a maximum rate in an optimum temperature range. The half time for precipitation is found to increase rapidly with a decrease in the initial concentration, again in accord with nucleation theory.

Plastic deformation (studied only in the case of N) was found not only to increase the rate of precipitation, but also to lower the final solution concentration presumably in equilibrium with the precipitate. It appeared, therefore, as if the precipitate induced by plastic deformation was not identical to that which forms in annealed material. This viewpoint was confirmed by metallographic examination which failed to reveal visible precipitates even after the final equilibrium solute concentration had been attained.

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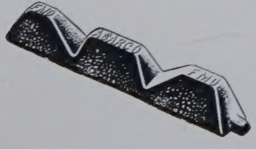

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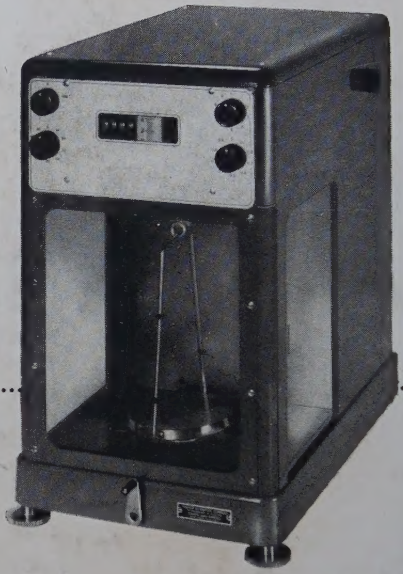

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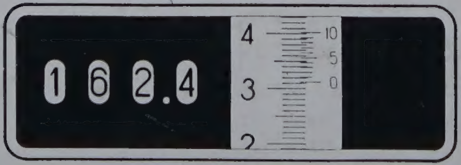

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